U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-258 849

Residual Waste Best Management Practices: A Water Planner's Guide to Land Disposal

PEDCo-Environmental, Inc, Cincinnati, Ohio

Prepared for

Environmental Protection Agency, Washington, D C Div of Water Planning

Jun 76

BIBLIOGRAPHIC DATA SHEET

1. Report No. AIR-48200-8/76-FR

2.

3. Recipient's Accession No. PB-259 532

4. Title and Subtitle
Development of Scientific Careers: The High School Years

5. Report Date August 1976 (date published)

6.

7. Author(s) Kevin J. Gilmartin, Donald H. McLaughlin, Lauress L. Wise, and Robert J. Rossi

8. Performing Organization Rept. No. AIR-48200-8/76-FR

9. Performing Organization Name and Address
American Institutes for Research
P. O. Box 1113
Palo Alto, CA 94302

10. Project/Task/Work Unit No. 48200

11. Contract/Grant No. EPP74-11549

12. Sponsoring Organization Name and Address
National Science Foundation
Washington, DC 20550

13. Type of Report & Period Covered
Final 7/1/74-8/31/76

14.

15. Supplementary Notes

16. Abstracts

An index of scientific potential was developed, which indicates the similarity between the pattern of a high school student's abilities and the abilities of earlier high school students who became scientists, engineers, or upper-level medical personnel. This index was used to explore the relations among abilities, interests, family background, school activities, extracurricular activities, science career plans, and entering a science occupation for two samples of high school students, one tested in 1960 and the other in 1975. Analyses concentrated on science career development as a function of ethnic group and sex. The scientific potential index was partialed out of the other variables, allowing an assessment of their relations to entering a science career when controlling for abilities. The study found three times as many female high school students planning science careers in 1975 as in 1960, with little difference between males and females in science abilities. Much larger differences in developed science abilities were found among the ethnic groups, with little evidence that the situation had improved in the last 15 years.

17. Key Words and Document Analysis. 17a. Descriptors

Personnel Development; Manpower Utilization; Scientists; Engineers; Medical Personnel; Aptitudes; Abilities; Psychological Tests; Vocational Interests; Employment; Ethnic Groups; Sex.

17b. Identifiers/Open-Ended Terms

Project TALENT; Career Plans; Career Guidance; Career Education.

PRICES SUBJECT TO CHANGE

17c. COSATI Field/Group 0509; 0510; 0511.

18. Availability Statement
Release unlimited.
Available through ERIC.

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 221

22. Price 7 75

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

1053

PB 258 849

WATER QUALITY
MANAGEMENT GUIDANCE
WPD EPA 440/9-76-022

RESIDUAL WASTE
Best Management Practices

A WATER PLANNER'S GUIDE TO LAND DISPOSAL

AUGUST 1976

Environmental Protection Agency
Water Planning Division
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No. PB258849

4. Title and Subtitle

Best Management Practices: A Water Planner's Guide to Land Disposal

5. Report Date

6.

7. Author(s) PEDCo-Environmental Specialists, Inc.

8. Performing Organization Rept. No. EPA-440/9-76-022

9. Performing Organization Name and Address

PEDCo-Environmental
Suite 13 . Atkinson Square
Cincinnati, Ohio 45246

10. Project/Task/Work Unit No. RFP No. WA-76-R045

11. Contract/Grant No. Contract No. 68-01-3503, Modification No.1

12. Sponsoring Organization Name and Address

U.S. Environmental Protection Agency
401 M Street S.W.
Washington, D.C. 20460

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

Water quality may be adversely effected by nonpoint sources of pollution even after significant measures have been taken and costs have been incurred for controling pollutants from point sources. Moreover, pollutants emanating from nonpoint sources result from improper deposition of residual wastes. Residual wastes can be more efficiently managed and thus reduce deterioration of water quality by applying cost effective state-of-the-art practices termed Best Management Practices (BMP's). BMP's may be applied individually or in combination-sequentially or simultaneously.

This Planner's Handbook for Residual Waste Management describes residual wastes from nine most frequently encountered sources and relates management of these wastes to exhaustive enumeration of BMP's. This will provide the potential users-planners, engineers, administrators, lawyers, elected officials and others, with a reference for carrying out their residual waste management responsibilities under areawide or State water quality management planning programs and other regional/local activities.

17. Key Words and Document Analysis. 17a. Descriptors

Residues, water, groundwater pollition, corrosion environments, hydrology, groundwater, precipitation, water conservation, water pollution, water quality, water treatment, water law, legislation, topography, landforms, terrain, chemical properties, soil properties, solubility, salinity, planning, site selection, regional planning, government, requirements, state government, public administration, law, public law, regulations, state law, management, management methods, management planning, financing, wastewater sludge, septage residuals, municipal refuse, industrial wastes, mining wastes, dredge spoil, land reclamation, land spreading, sanitary landfill, ocean disposal, trenching, infiltration, surface runoff, land disposal, environment

17b. Identifiers/Open-Ended Terms

Institutional considerations
Best Management Practices (BMP)
Residual wastes
Residual wastes management
Residuals utilization

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 290

22. Price $9.25-300

RESIDUAL WASTE BEST MANAGEMENT PRACTICES: A WATER PLANNER'S GUIDE TO LAND DISPOSAL

Project Officer
Dr. M. Dean Neptune

Contract No. 68-01-3503
Modification No. 1

U.S. ENVIRONMENTAL PROTECTION AGENCY
Water Planning Division
Planning Assistance and Policy Branch
Washington, D.C. 20460

June, 1976

ABSTRACT

The U.S. Environmental Protection Agency recognizes that water quality may be adversely effected by nonpoint sources of pollution even after significant measures have been taken and costs have been incurred for controlling pollutants from point sources. Moreover, some pollutants emanating from nonpoint sources result from improper deposition of residual wastes. EPA contends that residual wastes can be more efficiently managed and thus reduce deterioration of water quality by applying economical state-of-the-art practices termed Best Management Practices (BMP's). BMP's may be applied individually or in combination-sequentially or simultaneously.

This Handbook, Residual Waste Best Management Practices: A Water Planner's Guide to Land Disposal, describes residual wastes from nine most frequently encountered sources and relates management of these wastes to exhaustive enumeration of BMP's. This will provide the potential users - planners, engineers, administrators, lawyers, elected officials and others, with a reference for carrying out their residual waste management responsibilities under areawide or State water quality management planning programs and other regional/local activities.

This report is submitted in fulfillment of RFP No. WA-76-R045, Contract No. 68-01-3503, Modification No. 1, by PEDCo-Environmental Specialists, Inc. under sponsorship of the U.S. Environmental Protection Agency. Work was completed March 14, 1976.

ACKNOWLEDGMENT

The direction and assistance provided by Dr. M. Dean Neptune, EPA Project Officer, are gratefully acknowledged.

Cooperation of EPA professionals and others for reviewing drafts and providing information is appreciated.

Direction of this project for PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio, was conducted by Richard O. Toftner. Principal elements of the project were managed by Messrs. Charles Sawyer and Thomas Janszen.

Subcontractors preparing specific Handbook elements were Mr. George Wilson, Geraghty and Miller, Inc., Port Washington, N.Y., (Technical/Scientific); Mr. Donald Macdonald, Science Applications, Inc., LaJolla, Ca., (Legal/Institutional); and Dr. Samuel Fogel, Process Research Division, Environmental Research and Technology, Inc., Concord, Ma., (state-of-the-art review). Technical editing was performed by Ms. Anne Cassel of PEDCo.

TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1

2.0 RESIDUAL WASTE CATEGORIES 6

- 2.1 Wastewater Sludge 6
- 2.2 Septage Residuals 9
- 2.3 Water Treatment 12
- 2.4 Municipal Refuse 16
- 2.5 Combustion and Air Pollution Control Residuals 21
- 2.6 Industrial Wastes 25
- 2.7 Feedlot Residuals 30
- 2.8 Mining Wastes 39
- 2.9 Dredge Spoil Residuals 41

3.0 MANAGEMENT PRACTICES 51

- 3.1 Introduction 51
- 3.2 Residuals Utilization 52
- 3.3 Land Reclamation 57
- 3.4 Land Spreading 60
- 3.5 Sanitary Landfill 68
- 3.6 Ocean Disposal 93
- 3.7 Trench Sewage Sludge Disposal 93

TABLE OF CONTENTS (continued)

Page

3.8 Diversion and Drainage of Surface Runoff 95

4.0 TECHNICAL/SCIENTIFIC ASPECTS 103

4.1 Effects of Climate 103

4.2 Topography 111

4.3 Infiltration 113

4.4 Ground Water Hydraulics 118

4.5 Chemistry in the Subsurface 143

4.6 Vegetation 153

5.0 LEGAL/INSTITUTIONAL ASPECTS 164

5.1 Introduction to Legal Aspects of Residual Waste Management 166

5.2 An Introduction to Institutional Arrangements 188

6.0 APPLICATION OF MANAGEMENT PRACTICES 202

6.1 The Planning Process 202

6.2 Base Studies 203

6.3 Environmental Analysis 204

6.4 Organization 204

6.5 Financing 209

6.6 Case Study 211

APPENDIX A FIELD MONITORING AND SAMPLING A-1

APPENDIX B LABORATORY PROCEDURES FOR RESIDUAL WASTES B-1

APPENDIX C SITE EVALUATION CHECKLIST FOR LAND DISPOSAL OF RESIDUALS C-1

APPENDIX D GLOSSARY D-1

LIST OF FIGURES

Figure		Page
2-1	Geographic Distribution of Manure Production, 1975	36
3-1	Hydrogeology of Landfills with Ways of Using Underdrains to Control Leachate Migration	72
3-2	Shredding and Material Separation Process	79
3-3	Pictorial Representation of Properly Designed Chemical Landfill	88
4-1	The Hydrologic Cycle	106
4-2	Rock Texture in Major Aquifer Types	121
4-3	Diagram for Permeability, Transmissivity, and Hydraulic Gradient	126
4-4	Coutour Map of a Ground Water Surface Showing Flow Lines	127
4-5	Contaminant Flow in a Water-Table Aquifer	129
4-6	Plume of Contamination from an Industrial Waste Disposal Site	130
4-7	Effect of Differing Coefficients of Transmissivity Upon the Shape, Depth, and Extent of Cone of Depression.	132
4-8	Illustration of Interception of a Contaminated Ground Water Plume by a Pumping Well	133
4-9	Dilution Effects of Natural Ground Water on Contaminants from a Disposal Area	134
4-10	Sectional View of a Ground Water Mound	136

LIST OF FIGURES (continued)

		Page
4-11	Ground Water Flow in the Vicinity of a Mound	136
4-12	Comparison of Waste-Chloride Plumes in Snake River Plain Aquifer for 1968-1969, Based on Well-Sample Data and Computer Model	142
4-13	Soil Texture Triangle	147
4-14	The Nitrogen Cycle	149
6-1	The Planning Process	203
6-2	Environmental Analysis Flow	207
6-3	Central Region Organization of Governments Seven County Area (CROG)	214
6-4	Location of the Ten Major Wastewater Treatment Plants in CROG	221
6-5	Location of the Seven Water Treatment Plants	227
6-6	Areas Containing Sufficient Loess, Alluvium, and Glacial Drift to Allow for Landfilling and Land Spreading	232
6-7	Location of Abet Electric Power Plant	235
A-1	Paths of Contaminants from Disposal Site to the Environment	A-2

LIST OF TABLES

Table		Page
2-1	Typical Composition of Domestic Sewage	8
2-2	Typical Composition of Septage	11
2-3	Composition of Water Treatment Sludges	14
2-4	Projected Annual Generation of Municipal Wastes in United States	16
2-5	Municipal Refuse Generated in the United States in 1973 by Tons and Percentages	18
2-6	Typical Concentrations of Physical and Chemical Parameters in Leachate from Land Disposal of Solid Waste	20
2-7	Trace Elements in Fly Ash and Boiler Ash	23
2-8	Industrial Waste Parameters Having or Indicating Significant Potential for Ground Water Contamination	26
2-9	Domestic Animal Population in the U.S.; Past, Present and Projected Values	33
2-10	Annual Production of Livestock Manure: Past, Present, and Projected in Millions of Wet Tons	34
2-11	Animal Waste Generation for Selected Animals in Confined and/or Concentrated Areas	35
2-12	Manure Characteristics	37
2-13	Ranges of Minerals in Ash Content of Coal	40
2-14	Typical Leachate Analysis Mine Waste	40
3-1	Potential Materials Recovery from Selected Industries	55

LIST OF TABLES (continued)

		Page
3-2	Typical Dry Land Spreading Costs	67
3-3	Typical Solids Truck Transport Costs	67
3-4	Typical Landfilling Costs	77
3-5	Estimated Costs of Shredding and Material Separation, and Lagooning and Landfilling of Ash from Combustion in an Industrial Boiler	80
3-6	Estimated Costs of Incineration of Municipal Refuse and Disposal of the Resultant Ash	81
3-7	Estimated Costs for Shredding and Landfilling	82
3-8	Estimated Costs for Baling and Compacting Process	83
3-9	Typical Techniques Suitable to Treat Various Pollutant Contaminants	85
3-10	Cost for Various Landfill Liner Materials	87
3-11	Estimated Order-of-Magnitude Costs to Operate a 100 Ton/Day Chemical Landfill Site	90
3-12	Total Cost for Chemical Landfill Operation at Union Carbide's Institute, West Virginia Plant	91
4-1	Summary of Key Concepts Pertaining to Residuals Disposal on Land	104
4-2	Recommended Determinations for Background Ground Water Quality	112
4-3	Relation of Slope to Distance from Water Course	114
4-4	Relative Importance of Site Variables with Respect to Disposal Methods	119
4-5	Comparative Properties of Soil Colloids	145
4-6	An Outline Showing, in a General Way, the Changes that the Organic Compounds of Plant Tissue Undergo in the Soil	151

LIST OF TABLES (continued)

		Page
4-7	Removal Efficiencies of Major Constituents for Municipal Land-Application Systems	154
6-1	Items and Parameter of Items to be Considered in Environmental Analysis	205
6-2	Guides Helpful in Environmental Analysis	206
6-3	Summary of Existing and Projected Population	215
6-4	Summary of Existing and Projected Employment	215
6-5	Existing and Future Land Uses, Percent by Major Use	217
6-6	Current and Projected Sludge Generation in the CROG Area	219
6-7	Effects of Wastewater Sludges on Cost and Ground Water Quality from Various Disposal Practices	224
6-8	Present and Projected Municipal Refuse Tonnages for the Urbanized Areas of CROG	229
6-9	Ground Water Characteristics at the Landfill Site	233
6-10	Estimated Order-of-Magnitude Costs to Operate the CROG Areawide Chemical Landfill Site	239
6-11	Number of Feedlots by Animal Type and County	241
6-12	Projected Annual Livestock Populations and Manure Production	243
B-1	Methods of Preservation	B-2

1.0 INTRODUCTION

This report has been formulated as a "handbook" to guide water quality planners and decision-makers who are responsible in some way for management of residual wastes. The responsibility may lie directly within the structure of a State or areawide water quality management planning agency, or it may relate to other regional/local agencies and activities. We are concerned here not with limiting the applicability of the handbook, but rather with extending it to encompass all who may benefit from the information presented herein.

To exemplify the range of potential users, we cite the planning agency administrator; the engineer, scientist, economist, attorney or other legal specialist; the elected public official, the news media representative, and the interested layman. These and all other persons concerned with plans for meeting the mounting problems of residual waste management are potential users of this handbook.

RESIDUAL WASTE CATEGORIES

The U.S. Environmental Protection Agency defines residual wastes as follows:

> "Solid, liquid or sludge substances from man's activities in the urban, agricultural, industrial, and mining environment not discharged to water after collection and necessary treatment. These wastes include, but are not limited to: sludges resulting from water and domestic wastewater treatment, industrial sludges, utility plant sludges, and mining sludges; solids resulting from industrial and agricultural process waste materials and from nonprocess industrial and commercial wastes (e.g., demolition wastes, mine tailings, incinerator residues, dredge spoil, and agricultural waste like crop residues, feedlot wastes and pesticide containers); and liquids resulting from industrial side streams and from agricultural processes."

This definition contrasts sharply with more restrictive earlier thinking, in which the term 'residual wastes' denotes simply those wastes generated in treatment of wastewaters at municipal or areawide treatment plants. The definition has been broadened to match the increasing scope of residual waste problems. As a means of ordering this broader concept into manageable segments, this handbook considers frequently encountered residual wastes sources in the following nine major categories:

1. Wastewater sludge
2. Septage
3. Water treatment residuals
4. Municipal refuse
5. Wastes from combustion and air pollution controls
6. Industrial wastes
7. Feedlot wastes
8. Mine wastes
9. Dredge spoil

MANAGEMENT CONCEPTS

The term 'management,' as applied to residual wastes, implies a systematic and integrated approach to problem-solving, in which the environmental media (air, water, land) affected by man's disposal practices are viewed as a whole and are related as fully as possible to the other major facets of man's activities: the social, economic, institutional, and political structures of present-day life.

With respect to this overview of the total environment, a management practice cannot allow the simple shifting of a problem from one medium to another as, for example, in contamination of water supplies by residuals from devices installed to control air pollutants.

Planning for residual waste management involves consideration of these principal factors:

- Costs and benefits
- Scheduling and logistics
- Technological research and development
- Institutional arrangements
- Legal considerations
- Socio/political structures
- Public information and education

BEST MANAGEMENT PRACTICES

This handbook presents and exemplifies the concept of Best Management Practices (BMP's), which entail the coordination of management expertise with technology assessment to yield the best possible integrated management scheme for each specific situation. BMP's refer to a practice or combination of practices that is determined by a State after examination of alternative practices to be practicable and most effective in preventing or reducing the amount of pollution generated by a nonpoint source to a level compatible with water quality goals. BMP's involve applying a full array of management skills toward a single goal: meeting water quality and other environmental objectives at minimum cost. In applying BMP's the planner will look at residual wastes in nontraditional ways: he will consider waste materials not only as water quality problems but as potential assets. He will therefore emphasize (1) when possible, reducing at the source and recovering or beneficially utilizing resource values contained in such wastes, and (2) satisfactory land disposing of wastes presently unrecoverable. He will scrutinize closely the potential for reducing waste volumes at the source and intermediate handling steps to alleviate ultimate disposal problems.

BMP's are situation-specific. What constitutes a best management practice in XYZ County may not, and probably will not, provide the best solution for the problems of ABC County. Moreover, a single management technique, such as land application of sludge, does not become a 'best' practice until, having been evaluated among other alternatives, it is determined to be the optimum method in terms of costs and benefits, and is put into action.

A BMP may be applied on a short-term basis to resolve an existing problem with residuals; plans may include eventual phaseout of the practice as the situation is corrected or controlled. In such short-term applications to existing situations, the practices are constrained somewhat by in-place facilities, such as treatment works and industrial plants, and by existing governmental and administrative structures. In potential polluting situations, however, such as the planning of a new residential sector, an industrial/commercial complex, or a new town, the planner deals with a wider range of options. He is planning for the long term, and has opportunity for preventive application of best management practices.

In working with specific problems the planner will hope, of course, for an occasional breakthrough, an intuitive thrust that resolves an unmanageable problem. We tend to think of these as occuring mostly in technology - as sudden insights into materials, designs, and systems. They may occur also in the administrative end of management, when the planner detects a solution that has heretofore been hidden -- perhaps the design of an institutional structure that will effectively mesh the efforts of several fragmented groups.

Although such events are hoped for and encouraged, they are not the only form -- or even the major form -- of progress in residuals management. Progress may be realized also with every patient and painstaking effort of an individual planner. When he can elicit cooperative attitudes and develop working relationships among rival institutions, agencies, or groups, he is engaged in one phase of Best Management Practice.

PURPOSE OF THE HANDBOOK

This handbook is intended as a body of knowledge that can guide the planner toward Best Management Practices. It is not a design/construction manual with schematics for building a treatment plant or grading a landfill site. It is not an exhaustive treatise of legal ramifications and institutional planning techniques or a professional hydrogeologist's manual on hydrogeology. The technical discussions will not eliminate the planner's need for professional consultation. Rather, the level of technical exposition is intended to provide a background that will enable the planner to understand the problems of and to work knowledgeably with his technical consultants.

Organization of the handbook reflects the major elements involved in Best Management Practices and the underlying theme that successful management involves the continual integration of technical/administrative functions and skills.

The handbook gives information that will aid the planner in identifying problems. It provides guidance for the user in formulating preventive and ameliorative programs, in assembling staff and consultants, in developing and applying BMP's, and in assessing the degree of success achieved in residuals management efforts.

A USER'S GUIDE TO THE HANDBOOK

Residual Waste Categories (Section 2)

What must be disposed of	Defines nine major categories of residual wastes: ° quantities generated ° physical and chemical characteristics ° effects on the environment

Management Practices (Section 3)

How residuals are reduced, recovered for use, or disposed. Estimated costs	Describes basic techniques of residuals processing, recovery if possible, and disposal. Relates the management options to the categories of residuals discussed in Section 2. Gives estimated and average costs.

Technical/Scientific Aspects (Section 4)

Resource information on hydrogeology, topography, climatology Emphasis on groundwater systems	Provides background information that is useful in selecting technical consultants and key staff. Also useful in evaluating consultant and staff reports and performance. Reviews the basic phenomena that determine how residuals affect our water resources.

Legal/Institutional Aspects (Section 5)

How to establish a region wide management function Common legal problems how they are handled	Describes the principal constitutional and environmental legal problems in terms of liabilities, remedies, and institutional arrangements encountered in residuals and management. Describes the institutional options: the principal mechanisms for setting up a regionwide residuals management organization.

Application of Management Practices (Section 6)

Where to start and what to do in achieving BMP's	Provides guidance for developing a management program step by step. ° the planning process ° the base studies of a regionwide locale ° the full-scale environmental assessment ° the management organization ° the financing options
BMP's exemplified in case study	Presents a case study in which BMP's are developed from the planning stage through application in a hypothetical region exemplifying typical residuals disposal problems.

2.0 RESIDUAL WASTE CATEGORIES

The total body of materials encompassed by the term 'residual wastes' is a complex assortment of substances of diverse characteristics and modes of origin. The nine categories presented here are used throughout this handbook as a means of identifying and discussing some of the more prevalent types of residuals. These categories, based on source, are not to be considered as exhaustive or limiting, since they do not represent all possible types of residual wastes.

Each residual category presented here is analyzed in terms of sources, quantities generated, characteristics, environmental effects, and compliance requirements.

2.1 WASTEWATER SLUDGE

Sludge is the accumulated solids that are separated from liquids such as water or wastewater during processing; in addition, it is the precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater. Although the solids carried in wastewater represent less than 0.1 percent of the total weight of the wastewater flow, cost of their disposal represents 30 to 50 percent of the total cost associated with wastewater treatment (Ref. II-1). If proper care is not taken in handling and disposal, wastewater sludges can present a potential pollution hazard.

2.1.1 Sources of Wastewater Sludges

Currently there are over 21,000 publicly owned wastewater treatment plants in the nation (Ref. II-2). Sludges from typical secondary wastewater treatment plants come from the primary and final clarifiers. In advanced wastewater treatment (also called tertiary treatment), large quantities of chemical sludge are generated by the addition of lime to remove phosphorous.

2.1.2 Quantity of Sludge

The quantity of wastewater sludge generated in the United States in 1972 was 4.7 million tons (4.3 million metric tons) on a dry basis. It is estimated that sludge generation will increase to about 6.6 million tons (6 million metric tons), dry basis, by 1985 (Ref. II-3). For planning purposes, generation of primary sludge is typically about 0.12 pound (0.05 kg) per capita per day of dry solids, and generation of secondary sludge is about 0.08 pound (0.04 kg) per capita per day. · Many secondary and tertiary treatment processes require the addition of chemicals, which greatly increase the solids content of wastewater and the amount of sludge to be removed. Solids content ranges from approximately 0.04 to 0.35 pound (0.02 to 0.16 kg) of dry solids per capita per day (Ref. II-4). Introduction of wastewater from industrial sources into a treatment plant may increase the average sludge generation rate by 20 to 50 percent, depending upon the type of industry and its percentage contribution to the total daily flow of solids into the municipal treatment facility.

2.1.3 Characteristics of Sludge

Sludge is a mixture of organic and inorganic solid phases suspended in an aqueous solution. Primary sludge is gray and has an offensive odor. Solids content of primary sludge ranges from 2 to 7 percent. Activated sludge is brown, with no characteristic odor. Solids content ranges from 1 to 3 percent. Trickling filter humus is brownish. The fresh trickling filter sludge has a less offensive odor than primary sludge; its solids content range from 2 to 5 percent. Digested sludge is dark brown to black. If thoroughly digested, it has an odor similar to that of hot tar or burnt rubber.

Table 2-1 shows the typical composition of domestic sewage. The solids fraction of wastewater sludge is primarily composed of biodegradable organics (30%), stable organics (35%), and inorganic materials (35%) (Ref. II-5).

2.1.4 Environmental Effects

The disposal/utilization of sludges affects both the environment and its inhabitants in a variety of ways ranging from the nuisance of offensive odors to the health hazards of contaminated water supplies. Most complaints associated with sludge concern odors. The digestion process entails reduction in volatile solids contents, which stabilizes the sludge and reduces its odor potential. Of greater concern from the health protection standpoint, however, are problems of disease transmission, toxicities, and contamination of water supplies. The possibility of disease transmission resulting from disposal of sewage sludge on the land surface ranks as one of the primary objections to such practices (Ref. II-7).

Toxicity - Numerous heavy metals (zinc, copper, iron, lead, cobalt, cadmium, barium, nickel, boron, and arsenic) are present in wastewater sludge in varying quantities. The disposal of, for example, industrial sludges on agricultural land may impair the growth of crops because of the heavy-metal content or may endanger the food chain through excessive accumulation of these metals in the edible portion of the crops. These

Table 2-1. TYPICAL COMPOSITION OF DOMESTIC SEWAGE

(All values except settleable solids in mg/l).

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1,200	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable solids (ml/liter)	20	10	5
Biochemical oxygen demand, 5-day, 20 C (BOD_5)	300	200	100
Total organic carbon (TOC)	300	200	100
Chemical oxygen demand (COD)	1,000	500	250
Nitrogen (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorous (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chlorides[a]	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50

[a] Values should be increased by amount in carriage water.

Source: Ref. II-6.

asepcts are reviewed in depth by Chaney (Ref. II-8), Chaney and Giordano (Ref. II-9), Webber (Ref. II-10), and Page (Ref. II-11).

Ground and Surface Water Contamination - Surface waters can become contaminated during periods of rainfall when recently applied sludge materials are washed from the land surface.

The effects of groundwater contamination may not be immediately obvious, and they may continue for some time after corrective measures are instituted. The problem of groundwater contamination is highly complex, as described more fully in the technical discussions in Section 4.

2.1.5 Compliance Requirements

There are no Federal regulations governing land disposal of wastewater sludge. However, Section 405 of the Federal Water Pollution Control Act Amendment of 1972 (PL 92-500) contains provisions enabling EPA to issue National Pollutant Discharge Elimination System (NPDES) permits for the purpose of controlling contamination of navigable streams from improper sewage sludge disposal. Some states, however, follow Federal recommendations for various land disposal methods (Ref. III-39). Ocean disposal is regulated by the Marine Protection, Research and Sanctuaries Act, 1972 (40 CFR 220-227) and is discussed further in Section 3. The following additional sections of PL 92-500 relate to the production and disposal of wastewater sludges:

Section 201 - Construction of treatment works

Section 208 - Areawide waste treatment management

Section 301 - Effluent limitations

Section 306 - Effluent guidelines

Section 307 - Toxic and pretreatment standards

Section 402 - National Pollutant Discharge Elimination System (NPDES) permit requirements

Section 403 - Ocean discharge criteria

2.2 SEPTAGE RESIDUALS

Septage is a residual waste product of septic tanks that is produced nationwide in tonnages equal to the total production of sludge from municipal waste treatment plants as stated in section 2.1. Although the quantities are large, septage has received little attention from environmental engineers and scientists. Its fate in and effects on the environment are generally unknown (Ref. II-12). Disposal of septage poses many problems because regulatory agencies provide no detailed guidance on proper disposal methods. Some environmental problems resulting from septage concern artificial nutrients, pathogens and aesthetics (Ref. II-13).

2.2.1 Sources of Septage

Septage is the material that is pumped from septic tanks or cesspools. It is a sludge with solids content ranging from 1 to 8 percent, and is made up of settled materials, scum (floatable solids), and liquor.

2.2.2 Quantity of Septage

It is estimated that about 20 million dwellings in the United States have septic tanks, which serve populations of 70 to 80 million people (Ref. II-12, 13).

2.2.3 Quality of Septage

Septage can be characterized as a gray to black liquor sludge. Hydrogen sulfide, a product of anaerobic digestion, gives septage its characteristic offensive odor. The composition of septage is highly variable. Characteristic ranges of several septage parameters are presented in Table 2-2, along with two sets of average values.

Because of the common practice of discharging septage into municipal wastewater treatment plants, the septage composition shown in Table 2-2 can be compared with composition of a typical raw municipal wastewater to illustrate the magnitude of the differences. The suspended solids and nitrogen contents of septage are approximately 100 times and 20 times, respectively, more concentrated than those in raw domestic wastewater. These differences can upset operation of treatment plants and decrease treatment efficiencies.

2.2.4 Environmental Effects

Because of its anaerobic nature, bacteria inhabiting septic tanks must be at least facultatively anaerobic to grow in this environment. High counts of coliform bacteria, fecal streptococci, and pathogens such as *Pseudomonas aeruginosa*, staphylococci, salmonellae, and enteric viruses have been found (Ref. II-14). By any standards septic tank effluents represent a potential public health danger when left exposed and untreated.

The most common environmental problem related to the disposal of septage is artificial nutrient enrichment of surface and groundwaters. In areas where proper disposal is not practiced, accelerated eutrophication of ponds and rivers resulting from septage is common.

Table 2-2. TYPICAL COMPOSITION OF SEPTAGE

	mg/l		
Parameter	Range values[a]	Average values[b]	Average values[a]
BOD_5	2,000-25,000		
Total solids		41,900	39,500
Total suspended solids (TSS)	7,000-106,000	39,100	
Volatile suspended solids	(46-82% of TSS)	30,100	27,400
$COD_{soluble}$		3,360	
COD_{total}	5,000-80,000		60,600
Total Kjeldahl nitrogen			650
Ammonia nitrogen			120
Total phosphorous			214
Iron			163
Manganese			5.4
Zinc			62
Cadmium			0.2
Nickel			<1
Mercury			0.02

[a] Average of 21 different samples. Source: Ref. II-16.

[b] Average of 24 different samples. Source: Ref. II-12, 15.

Contamination of drinking water sources by nutrients contained in septage is also common. Nitrates, in particular, formed by the nitrification of ammonia, readily leach through soil and can contaminate wells. In areas where nitrates exceed the U.S. Public Health Service limit of 10 mg/l NO_2-N, the possibility of infants contracting methemoglobinemia is increased.

2.2.5 Compliance Requirements

There are no Federal requirements that deal with the disposal of septage. Responsibility for providing means of septage disposal is generally allocated to local boards of health, which are in turn responsible to state officials.

2.3 WATER TREATMENT

The sources of a public water supply are atmospheric (precipitation), ground (springs or wells), or surface waters (streams, rivers, lakes), all of which usually require some form of treatment before release into a modern water system. Atmospheric waters, generally understood to be rainwater and groundwaters do not require purification as extensive as that needed to prepare surface waters for domestic usage.

The residuals generated from water treatment processing are quantitatively comparable to tonnages generated nationally in wastewater treatment. In 1975 approximately 5.7 million tons (5.2 million metric tons) were generated. Much of the operation and maintenance of a normal treatment plant is in fact concerned with the handling and disposal of sludge.

2.3.1 Number of Plants and Residuals Sources

Although the locations of water treatment plants are population dependent, the Environmental Protection Agency currently estimates that some 240,000 public water systems will be subject to regulatory requirements developed under the Safe Drinking Water Act (Public Law 93-523) of 1974. From among this total distribution, about 200,000 are privately owned noncommunity systems serving a transient population, as at camp grounds, parks, and motels; the remaining 40,000 are community systems. Of the latter figure, 58 percent are publicly owned and produce some 88 percent of the total drinking water. A current EPA inventory of the national public water supply indicates that approximately 177 million persons are served by community water systems (Ref. II-17).

Residuals from the processing of these waters are dependent on the type of treatment. Most waste-producing water treatment plants use one or more of the following processes: softening; removal of iron and manganese; and coagulation, followed by flocculation and sedimentation. The resultant sludge is normally collected in sedimentation basins but may be secured through filtration. The process, therefore, affects the composition of the waste.

2.3.2 Quantity of Sludges

The total quantity of sludge generated in these waste-producing water treatment processes is estimated at 15,670 tons (14,228 metric) per day (1975) or a per capita rate of 0.177 pound (80.0 grams) per day. With the expected continuing increase in population, the projected sludge generation in 1995 will be about 18,717 tons (16,995 metric) per day, assuming the same per capita rate (Ref. II-18).

2.3.3 Quality of Sludges

Variability in the composition of water treatment sludges is shown in the characteristic ranges of several parameters presented in Table 2-3. Wastes resulting from different types of treatment processing can be characterized accordingly.

Sludges derived from coagulation may contain sand or silt, dissolved or colloidal organic material, microscopic organisms, and materials such as aluminum hydroxides or polyelectrolytes that stem from the chemicals used in the coagulation process. The sludge has a very low solids content, ranging downward from 2 percent, and has a gelatinous texture that makes dewatering difficult. The volume of sludge produced by a coagulation-flocculation plant usually ranges from 1 to 5 percent of the water treated. Water from filter backwash may contain particles of silt and aluminum, activated carbon, and suspended organic materials.

Sludges generated in iron and manganese removal processes are highly colored; they constitute a part of the filter backwash water. If the ratio of both constituents to silt or other easily filtered matter is high (as it is in some groundwaters), the sludges from iron and manganese removal are usually gelatinous and may be almost as difficult to dewater as sludges from coagulation plants.

Calcium carbonate is the main constituent in the sludges from chemical softening operations, usually accounting for 80 to 95 percent of the weight of solids in the sludge. Softening-derived sludges may also include hydrated oxides of magnesium, iron, aluminum, silt, and organic matter. They are usually easier to dewater than coagulant sludges, but the ease of dewatering varies widely. Factors that affect the treatability of the sludge include the ratio of calcium to magnesium and the amount of gelatinous solids present. Gelatinous solids may stem from colloids, iron and manganese, or other materials. The solids content of settled softening sludges can range from 2 to 30 percent. Their volume usually ranges from 0.3 to about 5 percent of the volume of water treated (Ref. II-20).

Table 2-3. COMPOSITION OF WATER TREATMENT SLUDGES

Parameter	Range values	No. of plants reporting the constituent
BOD_5	30-300 mg/l	-
COD	30-500 mg/l	-
Total dissolved solids	$\leq$4000 mg/l	-
pH	5-11 (pH units)	-
Total suspended[a] solids	1-8% of sludge by weight	-
Sulfate	$\leq$990 mg/l	-
Chloride	$\leq$990 mg/l	-
Fluoride	$\leq$0.01-3 mg/l	246
Cadmium	$\leq$0.01 mg/l	21
Copper	$\leq$0.23 mg/l	90
Nickel	$\leq$0.10 mg/l	21
Lead	$\leq$0.05 mg/l	43
Zinc	$\leq$0.67	44
Mercury	0.001 mg/l	1
Magnesium[a]	5-12% of sludge by weight	-
Calcium[a]	80-90% of sludge by weight	-

[a] Values obtained from personal communication with D. DeCarlo, Burgess and Niple Ltd.

Source: Ref. II-19.

2.3.4 Environmental Effects

The ultimate disposition of dewatered sludge from water treatment plants will require large land areas. These land requirements may prevent maximum beneficial utilization of land, and the disposal sites may be aesthetically unpleasant. Improper disposal can cause significant degradation of land surfaces. For example, the spray application of alum sludges to soil can possibly plug the surface, preventing further passage of water, and can kill vegetation or prevent its growth. Further discussion of soils and hydrology is presented in Section 4.

Of major concern is the impact on public health if the sludges contain toxic substances (heavy metals, e.g., cadmium, copper, nickel, lead, zinc and mercury). Agricultural usage of land on such a disposal site could result in toxic levels of these materials in edible foodstuffs. Consideration must be given also to pathogenic organisms carried in the sludge. Both toxic and pathogenic substances can contaminate surface and subsurface waters. Further, the attraction of insects and rodents to the disposal site could lead to distribution of pathogens in the surrounding area. Other possible effects involve changes in surface elevation, changes in soil characteristics, and land erosion.

A secondary environmental effect entails dissipation of disagreeable odors to the atmosphere from lagoon operations, for example. Landfilling operations may generate pollutants in the form of methane and other gases as well as fugitive dust from the application of soil cover.

Disposal of water treatment residuals in oceans or rivers is not recommended, because it may transmit toxic metals to the aquatic food chain. Other possible impacts are the occurrence of pathogens or odors along the shorelines, which usually include recreational and residential developments. Occasional washup and deposition of waste components on the shore also can detract aesthetically.

2.3.5 Compliance Requirements

There are no Federal regulations that deal with the disposal of water treatment residuals. Most States have some form of solid waste legislation, which is enforced with varying intensity. The residual most commonly addressed in these regulations is municipal refuse. Some States also regulate wastewater treatment sludges and septage; few states regulate the disposal of water treatment sludge. It is anticipated that this situation will change as the Safe Drinking Water Act (Public Law 93-523) evolves into regulations that can be enforced at the State level or by the local boards of health.

2.4 MUNICIPAL REFUSE

Municipal refuse includes both residential and common commercial waste materials. It is defined as any discarded solid materials, liquids absorbed in solid materials, or substances produced as a result of individual consumption, commercial enterprise, or institutional processes. Municipal refuse therefore can include such materials as paper, cloth, metals, glass, rubble, plastic, wood, food residuals, vegetable matter, animal wastes, and lawn and garden wastes.

2.4.1 Source of Municipal Refuse

Municipal refuse is generated from households, institutions, and commercial concerns such as hotels, department stores, schools, restaurants, and markets.

2.4.2 Quantity of Municipal Refuse

According to recent reports, approximately 144 million tons of municipal refuse was generated in the United States in 1973, giving a daily per capita rate of 3.75 pounds (1.7 kg) (Ref.II-21). Table 2-4 lists projected annual quantities of waste generation and per capita rates for the years 1980 to 1990. Metric equivalents are shown in parentheses.

Table 2-4. PROJECTED ANNUAL GENERATION OF MUNICIPAL WASTES IN THE UNITED STATES

	1980	1985	1990
Quantity of wastes generated, million tons (metric tons) per year	175(159)	201(183)	225(204)
Waste generation per capita per day, pounds (kg)	4.28(1.94)	4.67(2.12)	5.00(2.27)
Less resources recovered, million tons (metric tons) per year	19(17)	35(32)	58(53)
Net waste to dispose of, million tons (metric tons) per year	156(142)	166(151)	167(152)

Source: Ref. II-21.

The amount of residential refuse generated in an area is almost always directly proportional to the population, and per capita generation rates are usually fairly constant throughout the U.S. For example, a midwestern metropolitan area covering about 3.8 thousand square miles (9.8 thousand sq. km) having a population of about 1,471,000, generated 810,000 tons (735,480 metric tons) of municipal refuse in 1970. This is equal to a per capita rate of 3.02 pounds (1.37 kg) per capita per day (Ref. II-22). An area in the eastern United States covering about 3.4 thousand square miles (8.8 thousand sq. km) and having a 1975 population of 1,731,310 generated approximately 1,109,036 tons (1,007,005 metric tons) of municipal refuse. This is equal to a per capita rate of 3.51 pounds (1.59 kg) per capita per day (Ref. II-23). A rural area in the north central United States covering about 140 square miles (363 sq. km) with a population of 7,450 generated 4,245 tons (3,854 metric tons) of residential refuse in 1975. This is equal to a generation rate of 3.12 pounds (1.42 kg) per capita per day (Ref. II-24).

These values show the similarity of per capita generation rates throughout the United States and the relationship of total quantities generated to population density. It should be noted that if industrial wastes are figured into the per capita rates, they become very irregular and fluctuate greatly, depending on the types, sizes, and numbers of industries in a given area.

2.4.3 Quality of Municipal Refuse

Municipal refuse is usually 70 to 80 percent combustible material, the remaining 20 to 30 percent being comprised of glass, metals (ferrous and nonferrous), ceramics, and other miscellaneous inorganic materials. Municipal refuse has a moisture content of about 25 percent contained mostly in the combustible fraction (Table 2-5) (Ref. II-21, II-22). When separated from the noncombustibles, the combustible faction may yield heat values as high as 8,000 Btu per pound, (4444 kilogram-calories/kilogram) with a mean somewhere around 5,000 Btu per pound (2778 kilogram-calories/kilogram) (Ref. II-21, II-22).

Recoverable materials account for approximately 20 percent of municipal refuse by weight; glass and ferrous metals alone account for about 18.2 percent of the total recoverables (Ref.II-23).

2.4.4 Environmental Effects

How municipal refuse is handled and disposed of dictates the effects it will have on the environment. Materials not reduced or recovered for reuse must ultimately be disposed of on or in the land. For example, incineration may be used to reduce the volume of refuse, with the resulting ash ultimately placed on or in the ground. If resource conservation is practiced, the materials having no secondary use are ultimately

Table 2-5. MUNICIPAL REFUSE GENERATED IN THE UNITED STATES IN 1973 BY TONS AND PERCENTAGES

Type of waste	Quantity tons (metric tons) 1,000's	Percent of total waste
Durable goods:		
Major appliances	2,200 (1,998)	1.5
Furniture, finishings	3,400 (3,087)	2.3
Rubber tires[a]	2,000 (1,816)	1.4
Miscellaneous durables	7,100 (6,447)	4.9
Nondurable goods, except food:		
Newspapers[a]	10,400 (9,443)	7.2
Books, magazines[a]	3,720 (3,378)	2.6
Office paper[a]	6,390 (5,802)	4.4
Tissue paper, including towels[a]	2,320 (2,107)	1.6
Paper plates, cups[a]	600 (545)	0.4
Other nonpackaging paper[a]	1,300 (1,180)	0.9
Clothing, footwear[a]	1,300 (1,180)	0.9
Other miscellaneous nondurables[a]	1,900 (1,725)	1.3
Containers and packaging:		
Glass containers:		
Beer, soft drink	6,100 (5,539)	4.2
Wine, liquor	1,970 (1,789)	1.4
Food and other	4,330 (3,932)	3.0
Steel cans:		
Beer, soft drink	1,550 (1,407)	1.1
Food	3,140 (2,851)	2.2
Other nonfood	960 (872)	0.7
Aluminum:		
Beer, soft drink[b]	440 (400)	0.3
Other cans	50 (45)	<0.1
Aluminum foil	330 (300)	0.2
Paper, paperboard:		
Corrugated[a]	15,100 (13,711)	10.5
Other paperboard[a]	6,925 (6,288)	4.8
Paper packaging[a]	6,205 (5,634)	4.3
Plastics:		
Plastic containers[a]	510 (463)	0.4
Other plastic packaging[a]	2,580 (2,343)	1.8
Food wastes[a]	22,400 (20,339)	15.6
Yard wastes[a]	25,000 (22,700)	17.4
Miscellaneous inorganic wastes	1,900 (1,725)	1.3
Total	144,200 (130,934)	100.0

[a] Represents combustible fractions with total 76.9 percent of total generated municipal wastes.

[b] Includes all aluminum cans and aluminum ends from nonaluminum containers.

Source: Extrapolated from Ref. II-21.

disposed of in the ground. The most common means of refuse handling and disposal is land disposal; it is not sanitary landfilling, since most disposal operations do not meet the requirements for sanitary landfills. Placement of municipal residuals in the ground may lead to problems such as leachate from the refuse reaching ground and surface waters, attraction of vermin, and formation of methane gas and carbon dioxide at dangerous concentrations. Leachates may contain heavy metals at levels hazardous to health and also may contain disease-causing microbial life.

2.4.4.1 Microbial Life - Recent studies of municipal refuse show total viable bacterial populations that range from 4.0×10^6 to 6.8×10^8 organisms per gram and total coliform densities of 3.4×10^5 to 5.1×10^7 organisms per gram. Fecal coliform population in raw refuse ranges from 1.5×10^4 to 8.1×10^6 organisms per gram. These values indicate contamination of the refuse by fecal matter, which is one avenue of transmission of pathogenic microorganisms to the environment and man. These organisms are found in lesser quantities in dust from the refuse and also in stack gases from refuse incineration (Ref. II-25).

2.4.4.2 Physical and Chemical Parameters - Leachate from land disposal operations may contain high concentrations of substances that can cause adverse environmental impacts. Table 2-6 lists concentrations of various substances and other characteristics measured in leachate from a land disposal operation in the Midwest (Ref. II-26). The release of such materials into ground or surface waters could cause a potential hazard to the environment and to public health.

2.4.4.3 Other Environmental Problems - Insects and rodents are potential disease vectors in improperly operated landfills, resource recovery centers, and storage containers. In addition, to being aesthetically displeasing, uncovered wastes provide excellent breeding sites and food sources for rats, flies, and mosquitoes. Rats harbor ectoparasites which are known vectors of disease including murine typhus, salmonellosis, rat-bite fever, plague, tapeworm, and other diseases harmful to humans.

Various fly species are mechanical carriers of a large number of pathogenic agents. Typhoid, bacillary and amebic dysentery, diarrhea, and possibly salmonellosis, hepatitis, and poliomyelites are believed to be transmitted by flies.

2.4.5 Compliance Requirements

The Solid Waste Disposal Act, (PL 89-272), as amended authorizes the Administrator of the U.S. Environmental Protection Agency to encourage the enactment of improved and uniform State and local laws governing solid waste disposal. As a result, some States have enacted laws

Table 2-6. TYPICAL CONCENTRATIONS OF PHYSICAL AND CHEMICAL PARAMETERS IN LEACHATE FROM LAND DISPOSAL OF SOLID WASTE

Parameter	Concentration (ppm)	Parameter	Concentration (ppm)
COD	8,123	Calcium	9,862
BOD	23,938	Magnesium	62
NH_4	80	Manganese	18
Total solids	6,207	Iron	472
Disolved solids	6,038	Zinc	0.31
Alkalinity	2,620	Copper	0.05
Acidity	1,258	Lead	0.04
Hardness	2,573	Cadmium	0.01
Chloride	262	Nickel	0.17
Sulfate	98	Chromium	0.05
O-phosphate	17	Arsenic	0.06
pH	5.94 SU	Mercury	0.04
NO_2	0.036	Barium	0.49
NO_3	4.1	Selenium	<0.0015
Aluminum	1.1	Silver	0.04
Sodium	207	Fluorine	0.06
Potassium	197	Cyanide	0.02

Source: Ref. II-26.

regarding the disposal of solid wastes; solid waste legislation, however, is found in widely disparate portions of the various State codes. Many of these laws and codes are synopsized in a publication of the U.S. EPA (Ref. II-27). The synopsis also refers to many States which have developed solid waste regulations with standards for enforcement.

2.5 COMBUSTION AND AIR POLLUTION CONTROL RESIDUALS

The residuals from combustion and air pollution control systems are generated primarily by power plants, municipal refuse incinerators, and wastewater sludge incinerators. This section is concerned solely with residuals resulting from power plants, since those produced by the incineration of wastewater sludge and municipal refuse are discussed in Section 3.5.4.

2.5.1 Sources of Power Plant Residuals

Power plant residuals are a result of the waste materials contained in the fuels (oil and coal) used to fire power plant boilers. The major residual waste components of fuel are noncombustible ash and sulfur, which are concentrated by various collecting devices and pollution control systems and are then reused or ultimately disposed of.

The noncombustible ash portion of fuel occurs as boiler ash and fly ash. Boiler ash (bottom ash or boiler slag) is collected within the boiler. Fly ash is a finely divided aerosol contained in the combustion gases leaving the boiler. In facilities equiped with pollution controls, the fly ash is concentrated by such devices as cyclones and electrostatic precipitators. Because of the low ash content of fuel oil, the amount of ash generated by oil-fired boilers is minimal compared with the large volumes produced by coal-fired boilers.

Some power plants are equiped with systems for controlling emissions of SO_2. These systems produce a sludge that results both from the SO_2 removed and the chemicals (lime and limestone) used as sorbents in the removal system. The residuals generated in a power plant include the boiler ash, the fly ash, and the concentrated sludge.

2.5.2 Quantities of Residuals

The quantity of residuals produced by power plants depends on such factors as plant design, sulfur and ash contents of fuel, amount of fuel consumed, and type of waste-concentrating devices utilized. The quantities of ash and sludge generated on a nationwide basis therefore are not accurately known, although reasonable estimates are available.

2.5.2.1 Total Ash Quantities - Estimates based on coal consumption rates and average ash contents suggest that total ash production (fly ash and boiler ash) in 1975 totaled 44 to 50 million tons (40 to 45 metric tons) (Ref. II-28, 29). Projected increases in coal consumption indicate that this quantity could double by 1995 (Ref. II-30).

The rate of ash production averages 0.05 kg/kWh (based on an average fuel combustion rate of 0.4 kg/kWh and an ash content of 12%). Under these assumptions a relatively large facility of 1000 megawatts (MW) rated capacity would produce 287,000 tons (260,600 metric tons) of ash annually (Ref. II-28). The rate of ash production at a specific plant can be estimated with reasonable accuracy from the coal consumption and ash content data reported by that plant in FPC Report Form 67.

2.5.2.2 Scrubber Sludge Quantities - Because the technology is relatively recent, few full-scale SO_2 removal systems are in operation. Total generating capacity controlled by such systems in 1975 was less than 10,000 MW (roughly 3% of total coal-fired capacity in the U.S.). By 1980, approximately 90,000 MW of capacity should be controlled. If all new installations were to use lime or limestone additives, the total sludge generation in 1980 would be 13.1 x 10^7 tons (11.9 x 10^7 metric tons) (50% moisture). Sludge generation rates are expected to increase by 3 to 5 percent after 1980 (Ref. II-29).

2.5.3 Characteristics of Residuals

Fly ash is composed primarily of small-diameter particles ranging in size from less than 1 micron (1 x 10^{-5} centimeter) to 50 microns (5 x 10^{-4} centimeter). Most of the fly ash is in the 1 to 10 micron range. Mineral phases comprising the bulk material include glass (50-90%), hematite (1-8%), magnitite (0-30%), mullite (0-16%), and quartz (0-4%) (Ref. II-29).

The pH of fly ash ranges between 6.5 and 11.5, most samples showing a value near 11.0. Specific gravity ranges between 1.9 and 2.4.

Average particle size of boiler ash ranges from 0.025 to 0.25 centimeter (Ref. II-29). Specific gravity is typically 2.5, somewhat higher than that of fly ash.

The chemical constituents in fly ash that may pollute disposal areas or affect its reuse are silica (30-50%), alumina (20-30%), and ferric oxide (10-30%). Sulfur trioxide concentrations ranging from trace quantities to 6 percent have been reported. The other major components include lime (1.5 - 5%), moisture, and combustible matter (Ref. II-32).

Coal can contain a diversity of trace elements, concentrations of which are highly variable. On the average, Eastern coals show relatively higher concentrations of vanadium, mercury, lead, chromium, barium, boron, and zinc (Ref. II-28). Western coals may contain high concentrations of arsenic, selenium, antimony, and nickel (Ref. II-28).

Concentrations of trace elements in fly ash are higher than in boiler ash. Typical distributions of trace metals in fly ash and boiler ash are shown in Table 2-7.

Table 2-7. TRACE ELEMENTS IN FLY ASH AND BOILER ASH[a]

	(mg/kg)	
	Fly ash	Boiler ash
Arsenic	15.0	3.0
Mercury	0.03	<0.01
Antimony	21.0	0.26
Selenium	18.0	1.0
Cadmium	<0.5	<0.5
Zinc	70.0	25.0
Manganese	150.0	150.0
Boron	300.0	70.0
Barium	5000.0	1500.0
Beryllium	3.0	<2.0
Nickel	70.0	15.0
Chromium	150.0	70.0
Lead	30.0	20.0
Vanadium	150.0	70.0

[a] Source: Ref. II-28.

Approximately 1 to 5 percent of ash is water-soluble (Ref. II-28). The major dissolved species include sulfates, chlorides, and calcium ions. Arsenic, mercury, and cadmium compounds also are moderately soluble (Ref. II-32).

The principal physical characteristic affecting workability and disposal of scrubber sludge is the moisture content, which is primarily dependent on the amount of calcium sulfite (Ref. II-31,33).

The presence of fly ash in the sludge has a slight beneficial effect on the dewatering properties. At solids contents below 65 percent the scrubber sludge will not support equipment or personnel (Ref. II-31, 33). Achievement of sufficient solids content requires high concentration of $CaSO_4$. Otherwise sludges behave as bogs which rewater to solids contents of 35 to 50 percent.

The bulk density of settled sludge ranges from 0.05 to 0.054 pound per cubic inch (1.4 to 1.5 g/cm^3), depending primarily on moisture content. Specific gravity of the dry sludge material is about 0.09 lb per cubic inch (2.5 g/cm^3) (Ref. II-31)..

Analysis of a typical scrubber sludge at a plant burning eastern coal would show about 65 percent calcium sulfite ($CaSO_3 \cdot 1/2H_2O$), 5 to 7 percent calcium sulfate ($CaSO_4 \cdot 2H_2O$), 3 percent unreacted limestone ($CaCO_3$), 17 to 20 percent fly ash, and 3 to 5 percent other materials (Ref. II-31). Western coals yield sludges with somewhat more sulfate than sulfite (Ref. II-34).

2.5.4 Environmental Effects

The soluble portions of ash and scrubber sludge represent a potential threat to both ground and surface waters. Because solutions resulting from these wastes are usually alkaline, they may have a caustic effect on the receiving waters, possibly affecting the living organisms.

Release of trace elements to the environment is increasingly a matter of concern. Originating in the coal, these trace elements may occur in the fly ash or bottom ash, in the flue gas, or in the water used in system operations.

2.5.5 Compliance Requirements

Primary responsibility for the control of solid waste disposal lies with the States. However, guidance has been provided by U.S. EPA, Office of Solid Waste Management Programs for disposal of ash or scrubber sludge (Ref. II-27). Potential leachate from these sludges may be hazardous and ought to be regulated to protect water quality. Presently, few States have adequate regulations or uniform enforcement.

2.6 INDUSTRIAL WASTES

Industrial waste management problems are highly complex. A multitude of industrial sources are daily producing tons of residuals of diverse composition, many with high pollution potential. Table 2-8 lists the industries having a propensity for contaminating ground water. Since the destruction of chemical wastes still produces some residuals, these materials must be disposed of at properly located, designed, and monitored landfill sites.

2.6.1 Quantities

The current estimate of industrial waste generation, exclusive of boiler and fly ash residuals (see section 2.5.2.1), is about 210 million dry tons (190 million metric tons), per year (Ref. II-36). Current industrial growth and expansion indicate further increases. By means of recovery of valuable chemicals at the source, together with innovative process development and enforcement of pretreatment standards, industrial waste residuals on an order-of-magnitude basis might be reduced significantly.

2.6.3 Characteristics

Characteristics of industrial residual materials are highly variable. They can include industrial wastewater, industrial wastes, hazardous industrial wastes, and the residuals from treatment of industrial wastewater. If at all possible, the residuals suitable for ultimate disposal should be inert or nonreactive. Extreme care must be taken to prevent the mixing of unknown materials that might produce harmful reactions. Typical residuals generated by the industries listed in Table 2-8 are described below.

- Distillation Bottoms/Tops - Distillation is the separation of two or more materials in solution based on a difference in boiling points. The bottoms is the high-boiler material that is non-recoverable and must be properly disposed. Tops is the low-boiler material that falls outside product specifications (particularly during start-up) and if not reused, must be properly destroyed or disposed. Both the bottoms and tops are typically organic materials, the bottoms material being particularly complex and difficult to characterize.

- Oily Waste Residuals - In-plant sources of oily wastes include machine shop or repair shop waste oils, lubricating oils from process machinery leakage, refinery oil leaks or spills, and waste process oils used as heat transfer media. Typically an oil/water separator is utilized to separate oils from water-entrained effluent. The oily residuals in turn must be disposed.

Table 2-8. INDUSTRIAL WASTE PARAMETERS HAVING OR INDICATING SIGNIFICANT POTENTIAL FOR GROUND WATER CONTAMINATION

1. CHEMICALS AND ALLIED PRODUCTS

Organic Chemicals Industry

COD
pH
Total dissolved solids
TOC
Total phosphorus
Heavy metals
Phenol
Cyanide
Total nitrogen

Inorganic Chemicals, Alkalies and Chlorine Industry

Acidity/Alkalinity
Total dissolved solids
Chloride
Sulfate
COD
TOC
Chlorinated benzenoids and polynuclear aromatics
Phenol
Fluoride
Total phosphorus
Cyanide
Mercury
Chromium
Lead
Titanium
Iron
Aluminum
Boron
Arsenic

Plastic Materials and Synthetics Industry

COD
pH
Phenols
Total dissolved solids
Sulfate
Phosphorus
Nitrate
Organic nitrogen
Chlorinated benzenoids and nuclear Aromatics
Ammonia
Cyanide
Zinc
Mercaptans

Nitrogen Fertilizer Industry

Ammonia
Chloride
Chromium
Total dissolved solids
Nitrate
Sulfate
Organic nitrogen compounds
Zinc
Calcium
COD
Iron, total
pH
Phosphate
Sodium

Phosphate Fertilizer Industry

Calcium
Dissolved solids
Fluoride
pH
Phosphorus
Acidity
Aluminum
Arsenic
Iron
Mercury
Nitrogen
Sulfate
Uranium

Table 2-8 (continued). INDUSTRIAL WASTE PARAMETERS HAVING OR INDICATING SIGNIFICANT POTENTIAL FOR GROUND WATER CONTAMINATION

2. FOOD PROCESSING INDUSTRY

Canned and Preserved Fruits and Vegetables Industry

BOD
TOC
COD
Turbidity
Color
Ammonia
Phosphorus

Dairy Products Industry

BOD
TOC
COD
Turbidity
Color
Phosphorus

3. PAPER AND ALLIED PRODUCTS

Pulp and Paper Industry

COD
TOC
pH
Ammonia
Phenols
Sulfite
Color
Heavy metals
Nutrients (nitrogen and phosphorus)
Total dissolved Solids

4. PETROLEUM AND COAL PRODUCTS

Petroleum Refining Industry

Ammonia
Chromium
COD
pH
Phenol
Sulfide
Total dissolved solids
Chloride
Color
Copper
Cyanide
Iron
Lead
Mercaptans
Nitrogen
Odor
Total phosphorus
Sulfate
TOC
Turbidity
Zinc

5. PRIMARY METALS

Steel Industries

pH
Chloride
Sulfate
Ammonia
Cyanide
Phenol
Iron
Tin
Chromium
Zinc

Table 2-8 (continued). INDUSTRIAL WASTE PARAMETERS HAVING OR INDICATING SIGNIFICANT POTENTIAL FOR GROUND WATER CONTAMINATION

5. PRIMARY METALS (continued)

Metal Finishing Industry

Mineral Acids
Alkali
Chlorinated solvents
Hydrocarbon solvents
Chromate
Heavy metals
Cyanide
Grease
pH
COD
Turbidity
Color

6. TEXTILE INDUSTRY

Animal Fibers

BOD
TOC
Grease
Turbidity

Vegetable Fibers

BOD
TOC
COD
Sulfate
Sulfide
Chloride
Peroxide
Dyes
Alkali
pH
Sodium

Source: Ref. II-35.

- Lime Sludged Materials - Treatment of wastewater effluent with lime to precipitate heavy metals and control lime generates a sludge cake material. For example, spent electro-plating baths could be treated with lime in conjunction with ferric chloride or other coagulant aids to generate a sludge material that is settled out in a clarifier and dewatered by use of a rotary vacuum filter or centrifuge. The residual contains primarily heavy metals meshed in a lime matrix.

- Spent Filter Media - Media used to remove solids from gaseous or liquid streams e.g. filter paper, filter cloth, sand-beds, glass wool, spent carbon, and spent resins) periodically break down from extended usage and must be replenished. These spent media often contain entrained contaminants.

- Spent Catalysts - Catalysts for chemical reactions are often reused or recycled; however, it sometimes occurs that a catalyst becomes 'poisoned' and loses its effectiveness. Such 'spent' catalysts must be adequately destroyed.

- Dissolved Salts - Dissolved salts are often generated as unusable by-products from reactions in the inorganic chemicals, food processing, paper, and metals industries. Such salts as ammonium sulfate, and sodium nitrate, should be concentrated prior to disposal.

- Tank Storage Farm Runoffs - Stormwater runoff, leaks, or spills from tank storage areas must be contained and sumped to segregrated areas for pretreatment and disposal.

- Cleanout Residuals from Process Equipment Washes - All industries require periodic cleanout of process equipment. Such materials as solvents dilute acid solutions, dilute base solutions, and detergent rinses are typically used to clean process equipment. These washes must be contained, and pretreated and the residuals disposed of.

2.6.4 Environmental Effects

Case histories of industrial waste discharges into the environment are legend. In countless instances, flora and fauna, ground water, drinking water air quality, and human health have been affected negatively by industrial wastes. Once industrial pretreatment standards are effectively monitored and controlled, land application disposal of residuals must ensure protection from environmental hazards. By definition, 'hazardous wastes' are those wastes or combination of wastes that pose a substantial threat to human health or living organisms because they are lethal, nondegradable, or persistent, can be biologically magnified, or otherwise can cause or tend to cause detrimental cumulative effects. Hazardous wastes are categorized as toxic chemical, flammable, explosive, and biological (Ref. III-48). The ultimate disposal methods for industrial wastes must discern and separate hazardous from nonhazardous residuals.

2.6.5 Compliance Requirements

Federal legislation delineating pretreatment standards for various types of industries has not been enforced at the local level because compliance is not required until January 1977 (Ref. II-37). Some States have legislative requirements pending to control the disposal of industrial residuals in a specially designed chemical landfill. Among the different States, however, such control is highly variable and laws are not always enforced. Fewer than 10 States have authority to control hazardous waste disposed at designated sites. On-site disposal is subject to even less control.

2.7 FEEDLOT RESIDUALS

The United States industries inv[illegible] in agriculture produce large volumes of gaseous, liquid, and [illegible]id wastes annually. The greatest amount of wastes generated in agriculture result from animal excreta (feces and urine). The large quantities of manure generated on farms go unnoticed by most of the public, and only recently have environmental and agricultural specialists shown serious concern for the potential problems. Some of these problems are health-related and result from insufficient definition of local and national regulations and lack of sound technology for reuse or disposal of the wastes.

2.7.1 Sources of Livestock Wastes

Cattle (beef and dairy), hogs, poultry, and a collective class comprised of sheep, veal, and turkey are the major livestock animals contributing to the production of raw manure. Other farm animals, relatively minor contributors, are horses and ducks. The manure generated by farm animals falls either on open pasture land or in confinement facilities (feedlots). Confinement facilities are systems in which a large number of animals are held in a small area during most of their growth period and are provided with feed. In open confinement feedlots the livestock is exposed to atmospheric and climatic changes; in closed feedlots the humidity and temperature are controlled and the air is treated.

The animal excreta that falls on open pasture or grazing land presents few problems because it is dispersed relatively widely and the locations are usually remote from urban areas (Ref. II-4). Watering places at ponds and streams may be affected. The waste generated in confined facilities, however, is a highly concentrated source of potential pollutants.

The feedlot method of farming has developed into a large-scale enterprise in the United States; common in this industry are multihundred cow operations, multithousand beef or hog feedlots, and poultry farms involving many hundreds of thousands of birds. Moreover, as a result of increasing urban growth, decreasing amounts of available pasture and range, and increasing cost of farming, the number of animals fattened on feedlots is rising annually. Since the mid-1940's the total number of animals raised on feedlots or in confinement has nearly doubled (Ref. II-4). As the number of animals in confinement has increased, the number of operating feedlots has declined. Those involved in the feedlot industry are therefore producing greater concentrations of animal wastes, and this trend is expected to continue.

2.7.2 Quantity of Livestock Wastes

The steady rise in annual generation of raw manure is a result of the constantly increasing livestock population. The total population of the major classes of livestock on all farms (open pasture and feedlots) has increased from 2.9 billion in 1965 to 3.9 billion in 1975 (Table 2-9). This gain of approximately 1 billion animals represents an increase of 34 percent in 10 years. The rising trend of total livestock population is also expected to continue.

Production of future livestock populations involves numerous related factors, including human populations, per capita consumption of livestock products, yield per animal, grain supplies and prices, market prices, and state of the economy. Just as it is difficult to predict how these factors will change in the future, it is also difficult to determine their potential influence on livestock populations. A simple but realistic equation for predicting livestock populations can be formulated, however, on the basis of the following assumptions:

- per capita consumption of farm animal products will not change substantially in the next 20 years,
- yields per animal have also reached a peak, and
- human population increase will be the major factor influencing increases in farm animal production.

By use of projected human population values as estimated by the Bureau of the Census, and with 1975 livestock numbers as a base, future populations of farm animals can be calculated with the following growth equation:

$$N_t = N_0 e^{rt}$$

where,

N_t = projected livestock population,

N_0 = initial livestock population,

e = the constant 2.71828,

r = rate of population growth, and

t = amount of time elapsed between N_0 and N_t (Ref. II-8).

Projected livestock populations are shown by individual animal types in Table 2-9.

The annual quantity of manure generated by livestock on all farms (confined and unconfined animals) is calculated by selecting the appropriate values from Table 2-9 for use in the following equation:

$$\text{Annual wet tons of raw manure} = \text{animal population} \times \text{daily manure production} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ ton}}{2000 \text{ lb}}$$

Since 1965 the annual production of livestock manure on all farms has been more than 1.0 billion tons, and current volume is greater than 1.5 billion tons (1.36 billion metric tons) (Table 2-10). The amount of manure generated in confinement alone can be approximated by multiplying the maximum percent of animals in confinement times the total amount of waste produced annually on all farms. The annual manure production in confined facilities in 1975 is estimated to be 430 million tons (390 million metric tons) (Table 2-11).

The geographic distribution of manure, like that of farms and farm animals, is not uniform (Figure 2-1). It may be useful for the planner to know that the greatest accumulation of wastes is found in the corn belt, northern plains, and southern plains regions where large beef cattle and hog farms contribute the greatest percentage of the total manure produced. The mountain region and the lake states also generate large amounts of wastes annually.

2.7.3 Quality of Livestock Wastes

The properties of manure (feces and urine) depend on numerous factors such as animal species and age; digestibility, protein, and fiber contents of rations; and environment and productivity. Because of the variations in animal manures, the data describing manure characteristics, as in Table 2-12, should be regarded only as guidelines or estimates. Measured values in any specific manure analysis may easily deviate from those in the table by plus or minus 20 percent.

Table 2-9. DOMESTIC ANIMAL POPULATION IN THE U.S.; PAST, PRESENT AND PROJECTED VALUES (in millions)

	1965[a]	1970[a]	1975[b]	Projections			
				1980	1985	1990	1995
All Cattle	109.00	112.37	131.82	135.85	144.76	153.57	161.85
Beef	81.05	92.20	113.54	119.71	127.50	135.32	142.62
Dairy	20.16	15.97	15.31	16.14	17.26	18.25	19.23
Hogs	50.52	64.43	48.17	50.79	54.09	57.41	60.51
Poultry (all)	2,634.65	3,298.92	3,285.22[c]	3,464.03	3,689.29	3,915.46	4,126.52
Broilers	2,333.60	2,986.80	3,005.76	3,169.16	3,375.46	3,582.39	3,775.49
Others	301.05	312.92	279.46	294.67	313.83	333.07	351.03
Collective class (all)	58.05	141.02	141.14	148.82	158.50	168.22	177.28
Sheep	25.13	20.42	14.54	15.33	16.33	17.33	18.26
Veal	7.79	4.20	2.98	3.14	3.35	3.55	3.74
Turkeys	105.91	116.40	123.62[c]	130.35	138.82	147.34	155.28
Total (billions)	2.57443	3.61564	3.60635	3.79949	4.04664	4.29466	4.52616

[a] U.S. Dept. of Agriculture. Agricultural Statistics 1974. Washington U.S. Government Printing Office. pp. 630.

[b] U.S. Dept. of Agriculture. ERS/SRS. Agricultural Marketing Service. Livestock and Meat Statistics, Statistical Bulletin No. 543. Washington, U.S. Government Printing Office, 1975. pp. 151.

[c] U.S. Dept. of Agriculture. SRS. Crop Reporting Board. Eggs, Chickens, and Turkeys. Washington, U.S. Government Printing Office, January 1, 1976. pp. 18.

Table 2-10. ANNUAL PRODUCTION OF LIVESTOCK MANURE: PAST, PRESENT, AND PROJECTED IN MILLIONS OF WET TONS

(confined and unconfined animals)

	Average size, lb[a]	Daily production, lb/day-wet[a]	1965[b]	1970[b]	1975[b]	Projections[c]			
						1980	1985	1990	1995
All Cattle									
Beef	800-1000	53.0	783.9	891.8	1098.2	1157.9	1233.2	1308.9	1379.5
Dairy	1200-1400	100.0	367.9	291.5	279.4	294.6	315.0	333.1	350.9
Hogs	150	9.8	90.4	115.2	86.2	90.8	96.7	102.7	108.2
Poultry									
Broilers	2	0.14	59.6	76.3	76.8	81.0	86.2	91.5	96.5
Layers	4	0.21	11.5	12.0	10.7	11.3	12.0	12.8	13.5
Collective class			59.4	47.4	40.7	43.1	45.8	48.6	51.1
Sheep	100	4.0	18.3	14.9	10.6	11.2	11.9	12.7	13.3
Veal	150-250	16.0	22.7	12.3	8.7	9.2	9.8	10.4	10.9
Turkeys	18	0.95	18.4	20.2	21.4	22.7	24.1	25.5	26.9
Total (billions of tons-wet)			1.37	1.43	1.59	1.68	1.79	1.90	2.00

[a] Date are derived from Table 2-11 of the Livestock Waste Facilities Handbook, 1975. Midwest Planning Service. Iowa State University, Ames, Iowa.

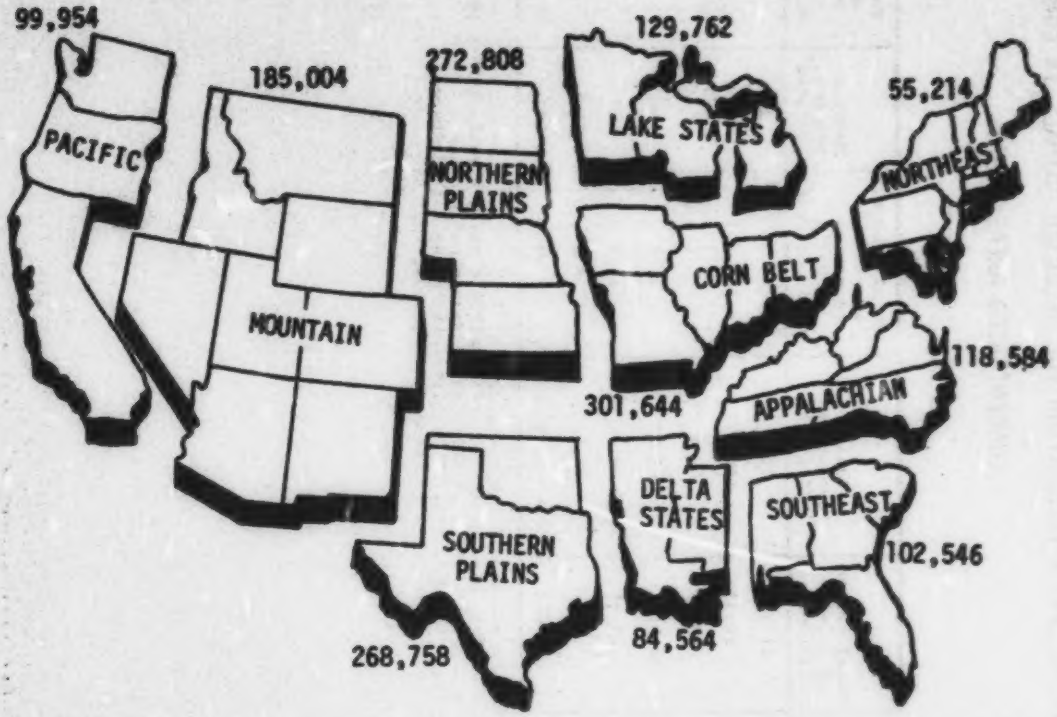
[b] Data are derived from Table 2-9.

[c] Data calculated using formula presented earlier in text, ($N_t = N_0 e^{rt}$).

Table 2-11. ANIMAL WASTE GENERATION FOR SELECTED ANIMALS IN CONFINED AND/OR CONCENTRATED AREAS (1975)

Animal type	Average size of animal, lb	Total number of animals, millions[a]	Daily production, lb/day-wet[b]	Total amount of waste generated annually, millions tons	Maximum percent confined[c]	Total annual generation of confined waste, millions tons	Percent of total confined waste generated
Beef cattle	800-1000	113.54	53.0	1098.2	12	131.8	30.7
Dairy cows	1200-1400	15.31	100.0	279.4	50	139.7	32.5
Swine	150	48.17	9.8	86.2	50	43.1	10.0
Chickens	4	3285.22	0.17	87.5	100	87.5	20.3
Sheep	100	14.56	4.0	10.6	20	2.1	0.4
Veal	150-250	2.98	16.0	8.7	50	4.4	1.0
Turkey	18	123.62	0.95	21.4	100	21.4	5.0

[a] Total numbers taken from those presented in Table 2-9.
[b] Daily production calculation as follows: lb/day = animal wt/1000 x raw manure in lb/day per 1000 lb.
[c] U.S. Environmental Protection Agency, Office of Solid Waste Management Program. Land availability, crop production and fertilizer requirements in the United States. EPA/530/SW-166. Washington, U.S. Government Printing Office, 1975. pp. 99.


99,954
PACIFIC
185,004
MOUNTAIN
272,808
NORTHERN PLAINS
129,762
LAKE STATES
55,214
NORTHEAST
CORN BELT
301,644
118,584
APPALACHIAN
SOUTHERN PLAINS
268,758
DELTA STATES
84,564
SOUTHEAST
102,546

[a] Values derived from: U.S. Environmental Protection Agency, Office of Solid Waste Management. Land availability, crop production and fertilize requirements in the U.S. EPA/530/SW-166. Washington, U.S. Government Printing Office, 1975. 99 p.

Figure 2-1. Geographic distribution of manure production, 1975. Values in wet tons per year.[a]

Source: U.S. Department of Agriculture.

Table 2-12. MANURE CHARACTERISTICS[a]

Animal	Size, pounds	Total manure production,			Water, %	Density, lb/cu ft	TS, lb/day	VS, lb/day	BOD5, lb/day	Nutrient content		
		lb/day	cu ft/day	gal/day						N, lb/day	P, lb/day	K, lb/day
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dairy cattle	150	12	0.19	1.5	87.3	62	1.6	1.3	0.26	0.08	0.010	0.04
	250	20	0.32	2.4	87.3	62	2.6	2.1	0.43	0.10	0.020	0.07
	500	41	0.66	5.0	87.3	62	5.2	4.3	0.86	0.20	0.036	0.14
	1000	82	1.32	9.9	87.3	62	10.4	8.6	1.70	0.41	0.073	0.27
	1400	115	1.85	13.9	87.3	62	14.6	12.0	2.38	0.57	0.102	0.38
Beef cattle	500	30	0.50	3.8	88.4	60	3.5	3.0	0.80	0.17	0.056	0.12
	750	45	0.75	5.6	88.4	60	5.2	4.4	1.2	0.26	0.084	0.18
	1000	60	1.0	7.5	88.4	60	7.0	6.0	1.6	0.34	0.11	0.24
	1250	75	1.2	9.4	88.4	60	8.7	7.4	2.0	0.43	0.14	0.31
cow[b]		63	1.05	7.9	88.4	60	7.3	6.2	1.7	0.36	0.12	0.26
Swine												
Nursery pig	35	2.3	0.038	0.27	90.8	60	0.20	0.17	0.07	0.016	0.0052	0.010
Growing pig	65	4.2	0.070	0.48	90.8	60	0.39	0.31	0.13	0.029	0.0098	0.020
Finishing pig	150	9.8	0.16	1.13	90.8	60	0.90	0.72	0.30	0.068	0.022	0.045
	200	13	0.22	1.5	90.8	60	1.2	0.96	0.39	0.090	0.030	0.059
Gestate sow	275[b]	8.9	0.15	1.1	90.8	60	0.82	0.56	0.27	0.062	0.021	0.040
Sow & litter	375[b]	33	0.54	4.0	90.8	60	3.0	2.4	1.0	0.23	0.076	0.15
Boar	350[b]	11	0.19	1.4	90.8	60	1.0	0.84	0.35	0.078	0.026	0.051
Sheep	100	4.0	0.062	0.46	75	65	1.0	0.85	0.09	0.045	0.0066	0.032
Poultry												
Layers	4	0.21	0.0035	0.027	74.8	60	0.053	0.037	0.014	0.0029	0.0011	0.0012
Broilers	2	0.14	0.0024	0.018	74.8	60	0.036	0.025	0.0023	0.0024	0.00054	0.00075
Horse	1000	45	1.5	11	79.1	30	9.4	7.5	-	0.27	0.046	0.17

[a] Data are derived from Table 2-11 of the Livestock Waste Facilities Handbook. 1975. Midwest Planning Service. Iowa State University, Ames, Iowa.

(1) lb/day = animal wt/1000 x R.M. in lb/day per 1000 lb.
(2) cu ft/day = lb/day ÷ density
(3) gal/day = 7.5 x cu ft/day
(4) Water % = 100 - % RM from Table 2-11, Livestock Waste Facilities Handbook.
(5) density = best estimate. not American Society of Agricultural Engineers (ASAE) data.
(6) TS = lb/day x TS as % RM from Table 2-11, Livestock Waste Facilities Handbook.
(7)-(11) lb/day of element = TX x % TS of element.

[b] Not ASAE data: assumptions:
cow = 1.05 cu ft/day
gestating sow = 1/2 of ASAE data for her weight because she's limit fed.
sow & litter = ASAE data for her weight + 8 pigs (@ 1.0 lb/day).
boar = 1/2 of ASAE data for his weight because he's limit fed.

Generally speaking, fresh manure contains 75 to 88 percent water (Ref. II-39). The remaining constituents are inorganic and organic solids, liquids, gases and microbial cells. Estimates show that 90 percent of the dry matter in manure is organic wastes from digestion of feeds (Ref. II-40).

The large concentration of organic matter in animal manure presents a major problem in treating this waste. The BOD in various animal manures has been calculated to be 100 to 300 times greater than that occurring in untreated domestic sewage (Ref. II-40). The COD content of animal wastes is estimated to be 100 to 400 times greater than that in domestic sewage.

Manure contains all the inorganic nutrients required by plants although the proper quantities may not always be present.

The major microbial constituents of animal manure are bacteria, fungi, actinomycetes, and protozoa. Enterococci and coliforms are very numerous, some coliform counts showing as high as 18 billion excreted per animal per day (Ref. II-40). It is these organisms that are the carriers of various diseases associated with animal wastes.

The chemical and biological parameters presented here relate to raw manure and are not representative of feedlot runoff. Detailed information on the composition of feedlot runoff in areas of different climatic conditions (Nebraska and Colorado) is given in a recent EPA publication (Ref. II-11).

2.7.4 Environmental Effects of Livestock Wastes

The major hazards to surface and ground waters arising from animal manures are oxygen-demanding matter (BOD's and COD's), plant nutrients, dissolved and suspended solids, and pathogenic agents. Odor and color are potential pollutants of lesser importance.

The flow of organic matter from livestock facilities into aquatic systems places an oxygen demand on the receiving waters. If sufficient organic matter enters these waters, oxygen concentrations may drop below the levels necessary to support aquatic life; if this depletion of oxygen continues, anaerobic conditions may develop. Several reports have shown that fish kills in some streams resulted directly from feedlot runoff (Ref. II-40).

Pathogenic organisms in livestock wastes are another source of pollution of aquatic environments. These infectious agents may infect animals and human beings. The potential water-borne diseases transmitted by livestock include anthrax, brucellosis, coccidiosis, encephalitis, erysipelas, Newcastle disease, ornithosis, gastroenteritis, and salmonellosis.

All of the parameters just described are potential polluters of groundwaters as well as surface waters. As a result of soil compaction by animal hooves, however, the percolation of hazardous materials into the ground under the feedlot is minimal. Surface runoff occurs when pollutants migrate from the feedlot to streams or are transported through permeable soils to the aquifer (see Section 4).

2.7.5 Compliance Requirements

The U.S. EPA proposed regulations relating to concentrated animal feeding operations and plans to promulgate these regulations in 1976. The basic provisions of the proposed regulations appeared in the Federal Register, November 20, 1975 (Ref. II-42).

State agencies can impose additional or more stringent requirements, such as greater runoff holding capacity, specified times for land application, and procedures for groundwater protection. Other regulations, such as zoning laws and public health laws relating to milk production, may affect the design, construction, and operation of a livestock facility and its manure management program. Some agencies attempt odor control by regulating the distance between public housing and livestock production and waste control facilities.

2.8 MINING WASTES

Mining wastes are residual products of mining and ore processing. Various environmental and industrial groups have given significant attention to the disposal of mining wastes, and to some extent disposal in an environmentally acceptable manner is general practice among mining companies. The characteristics of mining wastes and their effects on the environment are being studied. In particular, much work has been done on waste from bituminous coal mines.

2.8.1 Sources of Mining Waste

Mining wastes result from the mining and processing of minerals. The wastes consist of all nonore-bearing materials including rock, clays, sandstone, and ore-related materials.

2.8.2 Quantity of Mining Wastes

Mining waste from fuel and nonfuel minerals in 1973 was estimated to be 2.5 billion tons, which resulted from producing approximately 2.9 billion tons of mining products (Ref. II-43).

2.8.3 Quality of Mining Waste

Mining wastes consist of rock and related ore-bearing materials. For example, waste from mining of bituminous coal contains sandstone, shale, pyrites, clays, limestone, traces of coal, and locally occurring minerals associated with the coal seam.

The minerals associated with ores have been characterized and quantitatively analyzed, as shown in Table 2-13.

Table 2-13. RANGES OF MINERALS IN ASH CONTENT OF COAL

(percent)

Quartz	2 - 22
Calcite	0 - 17
Pyrite	8 - 40
Iron sulfate	0 - 32
Clay	24 - 71
Kaolinite	7 - 17
Illite	8 - 36
Shale	5 - 27

Source: Ref. II-44.

In addition to the solid waste material, mining operations produce both gaseous and liquid wastes as decomposition products or leachates.

Gaseous decomposition products include H_2S, CO, smoke, and SO_2. These products result when combustible materials in mine waste piles begin to burn.

Liquid wastes result from the leaching of water-soluble components of mining wastes. Typical composition of the leachate is shown in Table 2-14.

Table 2-14. TYPICAL LEACHATE ANALYSIS MINE WASTE (ppm)

	Fe	Al	Ca	Mg	Mn	Si	Ni	SO_4	pH
Mine Water A	904	74	189	66	14	24	35	1412	2.7
Mine Water B	244	8	181	74	4	14	70	1127	4.9

Source: Ref. II-45.

Composition of the liquid waste varies with the associated mineral bed. The heavy metals can include iron, zinc, and lead. The principal contaminant is usually iron, present in the ferrous state, which is oxidized in air to the ferric state. The ferric iron forms insoluble hydrous iron oxide at pH above 3, producing a reddish liquid discharge.

2.8.4 Environmental Effects

Burning mine waste piles emit CO, CO_2, H_2S, SO_2, smoke, and unburned hydrocarbons, some of which are known to produce adverse health effects. Little work has been done in characterizing the quantity of emissions and analyzing the minor constituents of gases emanating from mine waste piles. These burning piles are predominantly located in coal mine regions where the refuse contains significant amounts of combustible material.

By far the most hazardous pollutants carried by mining wastes are the liquid leachates. These wastes can contain heavy metals and hydrolyzable salts, which form suspended solids and acids. The suspended solids can cause coloration of the receiving water and in great enough quantities can settle and destroy the bottom life (benthos) of the receiving stream.

2.8.5 Compliance Requirements

Some States (eg., W. Virginia, Wyoming, etc.) in which mining occurs have regulations relating to the disposal of solid wastes from mining operations. These regulations, which are often loosely enforced, involve the use of impoundment, construction of waste piles, control of burning waste piles, control of fugitive dust emissions, and control of liquid discharges. In addition, some States (eg., Ohio) have regulations concerning reclamation of mined land, especially of strip-mined land. The Federal and State agencies involved in control of mine waste disposal include the Federal and State environmental agencies, the U.S. Bureau of Mines, the Federal Mine Environmental and Safety Administration, and State mine safety inspectors.

The U.S. EPA is now formulating effluent guidelines and standards for mineral mining and processing point sources (Ref. II-46). In addition, EPA is establishing specific effluent guidelines and standards for coal mining point sources (Ref. II-47). The principal difference between their regulations and existing State regulations is the inclusion of proposed effluent limitations on aluminum, manganese, nickel, zinc, dissolved iron, and total suspended solids. Current regulations concern only total iron, pH, acidity, and alkalinity.

2.9 DREDGE SPOIL RESIDUALS

Dredge spoil is commonly any sediment removed from aquatic environments. These sediments may be deposited by natural erosion and sedimentation processes or by industrial or municipal discharges of sludge or suspended solids such as street litter.

2.9.1 Sources of Dredge Spoil

Most dredge spoil is generated by the U.S. Army Corps of Engineers in their channel maintenance projects. On an average, approximately 300 million cubic yards (229 million cubic meters) are generated annually by maintenance dredging; 80 million cubic yards (61 million cubic meters) are generated by new work dredging, i.e. construction of harbors and channels, drainage ditching, channel realignment, and construction of water supply storage facilities (Ref. II-48).

Dredging operations range from small projects involving only a few thousand cubic meters and lasting a few days, to extensive developments involving millions of cubic meters and lasting years. Typical operations as reported by one large dredging firm generally range from 20,000 to 150,000 cubic yards (15,000 to 115,000 cubic meters) (Ref. II-49).

2.9.2 Quantity of Dredge Spoil

From 1824, when the Army Corps of Engineers was authorized to develop and maintain navigable waterways, through 1971 over 22,000 miles (35,000 km) of waterways have been dredged by the Corps. The Corps presently maintains over 19,000 miles (30,000 km) of waterways involving about 1000 projects. In 1971, the Corps removed 390 million cubic yards (298 million cubic meters) of sediments from waterways. Sixty-nine percent of this spoil was considered to be nonpolluted (Ref. II-48).

Most dredging by the Corps takes place in the southeastern United States, a significant portion in the Mississippi River valley (Ref. II-50).

2.9.3 Quality of Dredge Spoil

The physical, chemical, and biological nature of dredge spoil is highly variable. Spoil can occur in the form of clean sand or gravel with very little organic matter. It can be made up of organic silts and clays of natural origin or it can originate from municipal or industrial operations and consist of highly polluted organic sediments with a very high BOD.

Chemically, the spoil may be relatively inert and free of pollutants or it may contain high concentrations of exotic toxic chemicals such as polychlorinated biphenyls (PCB's), chlorinated hydrocarbons, or organic and inorganic chemicals. In harbors receiving overflows of stormwater and sewage, heavy metals such as copper, chromium, lead, mercury, and zinc may also accumulate to high concentrations in highly organic muds. A direct correlation between percent organic matter and heavy metal content has been demonstrated (Ref. II-51, 52, 53).

Biological activity in spoil varies with its physical and chemical characteristics. Clean sands usually exhibit highly diversified types of organisms, whereas polluted sediments contain "pollution tolerant" organisms, such as tubifex worms and leeches, or marine polychaetes and annelids. Sediments containing toxic substances contain only very few "pollution tolerant" species or no organisms at all (Ref. II-54).

2.9.4 Environmental Effects

Depending on the amount and type of spoil, some predictions can be made relative to the ability of bottom dwelling (benthic) organisms to respond to burial. Attached sessile (nonmobile) organisms are usually killed by burial. Some oyster beds have been totally obliterated by direct dumping of spoil material (Ref. II-55).

Other organisms may survive burial at different levels. Organisms with restricted mobility, such as hard-shelled clams, can survive burial only to a few centimeters of spoil material. Benthic organisms with good mobility, such as marine polychaetes, can survive burial with up to 21 cm of silt (Ref. II-56).

Many dredging sites, especially inner harbors of large cities, yield sediments that contain large concentrations of organic materials and thus impose a high oxygen demand on the surrounding environment (Ref. II-53, 57). When these organic-rich sediments are disposed of in an area inhabited by benthic organisms, the probability of suffocating them is great (Ref. II-56).

High concentrations of heavy metals, petrochemicals, or other toxic substances, which occur most often in metropolitan or industrial regions, will preclude the formation of viable populations of benthic organisms. Lower concentrations can have sublethal effects, causing avoidance reactions, reduced growth, or decreased reproduction. Bioaccumulation of toxic substances through the food chain can render fish or shellfish unfit for human consumption (Ref.II-58).

Application of dredge spoil to the land poses potential pollution problems, principally from heavy metals and nitrogenous wastes, both of which can seriously degrade water supplies.

Nitrate-nitrogen is not acceptable in water supplies, at levels exceeding 10 mg/l (Ref. II-58). It is imperative, therefore, to calculate maximum loadings of nitrogenous materials and potentially toxic heavy metals and to determine that safe levels are not exceeded when dredge spoil is used for land reclamation.

2.9.5 Compliance Requirements for Disposal of Dredge Spoil

Responsiblity for the disposal of dredge spoil material is charged by the Corp of Engineers and the EPA. Permits for ocean disposal must be obtained from EPA or the Corps under EPA review. Disposal sites are selected in accordance with specific guidelines, and the EPA Administrator is authorized to deny or restrict use of a proposed disposal site when he determines that discharge of dredge spoils will adversely affect the aquatic environment. As a further safeguard, the Corps has developed a "Standard Elutriate Test" to be performed on all dredge spoil prior to its disposal (Ref. II-59).

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3.0 MANAGEMENT PRACTICES

3.1 INTRODUCTION

We speak of 'management' of residuals rather than simply of disposal techniques because the complexity of residuals handling on an areawide or Statewide basis demands the ability to formulate and administer a systematic program. The term 'management' implies an overview, in which diverse components are integrated to yield efficient and effective performance. In management of residual wastes, the options are many and the relationships are complex.

As an example, consider a single management practice: the land application of stabilized sludge from wastewater treatment. Management of such a program would entail first, an evaluation of sludge to be disposed and review of possible beneficial or adverse consequences of sludge application. Second, there must be an evaluation of the sludge in terms of proposed utilization or disposal sites and constituents, including possible hazardous or toxic substances. If the sludge is produced by treatment of wastewaters that include a contribution from industrial sources, further complexities arise. Pretreatment of the industrial wastewaters may be required, and such pretreatment usually entails yet another residual, which in turn must be utilized or disposed of in a manner protective of air and water quality.

When all required steps have been taken to reduce volume, recover valuable constituents, or to ensure the final suitability of the sludge for disposal at the proposed sites, management of the program entails further responsibilities: training of operators to ensure proper application and maintenance procedures; establishment of a monitoring system that will promptly detect any adverse effects of the operation (see Appendix A); provision for occasional independent surveillance as backup for the routine monitoring; formulation of procedures for cost accounting, record-keeping, and reporting; continuing assessment of developing technologies. These activities represent some, but not all, of the intricate aspects of residuals management.

This section of the handbook is devoted to a review of current practices for management of residuals of the nine categories described in Section 2. The intention is to acquaint the user of the handbook with the fundamental methods of residuals management as an aid to his development of an integrated program that exemplifies Best Management Practices (see Section 6).

Two further concepts are essential to analysis of residuals management practices. First is the distinction between preventive practices, aimed at controlling recycling/disposal operations in the planning or design phase, and ameliorative practices, which deal with improvements in existing methods of disposal. In the design of a proposed new landfill operation, for example, the planner engages in preventive management by calling on all available technical/scientific expertise to ensure optimum safeguarding of environmental quality. Faced with an ongoing landfill operation, however, the planner must apply ameliorative practices to lessen already harmful environmental impacts by such means as sealing, construction of diversion ditches, or other remedial techniques.

A second concept basic to residuals management is the distinction between utilization and disposal. In utilization practices the residual becomes a resource; it provides benefits or values, such as improvement of soils or materials for construction. In disposal practices the residual is not used for any beneficial purpose.

In residuals management the first goal is to initiate preventive practices. Utilizing the residual whenever possible rather than simply disposing of it may be a preventive practice.

This section describes some of the principal methods of residuals management: source reduction, recycling/recovery, reclamation, land application, landfill, lagooning, and ocean disposal. These practices entail a variety of auxiliary residuals-handling techniques, which are described briefly. This total repertoire of management practices is related also to the major categories of residuals, so that the planner may determine the options from which to develop the Best Management Practices in his given situation (See Section 6).

3.2 RESIDUALS UTILIZATION

The positive impacts of residuals utilization are impressive:

- Natural resources are conserved.
- Detrimental effects of disposal are reduced.
- Consumption of energy is reduced.
- Net costs can be reduced as environmental benefits are accrued.

Although recycling of consumer goods, such as paper, cans, and automobiles has increased in recent years, the proportion of the nation's material requirements that is satisfied by recycled materials has decreased or remained constant (Ref. III-1). Principal constraints to extensive recycling programs are institutional, economic and technological. The following discussion considers three classes of materials to illustrate the positive environmental and energy-related effects of residuals utilization.

3.2.1 Utilization Practices for Specific Residuals

Wastewater and Water Treatment Sludges

Many wastewater and water treatment sludges are chemically treated to aid in flocculation, coagulation, and resedimentation. Generally, the chemical treatment consists of the addition of ferric or aluminum salts, lime, or high-molecular-weight polyelectrolyte compounds.

Sludges containing alum may be treated with acid (Ref. III-2), to reduce pH to 2.5 to 3.0, or with base (Ref. III-3), to increase the pH to 12.0 to 12.5. Generally acid treatment is the more economical method, giving an alum solution that can then be recycled into the waste stream.

Lime may be recovered through the recalcination process, which basically involves the heating of dewatered calcium-containing sludge to 1850°F in a six-hearth recalcining furnace. Since 1968, the Lake Tahoe Wastewater Treatment Plant has been able to recover 72 percent of its lime through this process (Ref. III-4).

Sewage sludge also contains the major plant nutrients (nitrogen, phosphorus, and potassium) as well as large amounts of organic matter beneficial to soil. Because of these constituents, stabilized heat-dried or air-dried sludges are a desirable soil amendment. In 1975, the Metropolitan Sewer District of Greater Chicago (Ref. III-5) distributed to gardeners over 213,000 cubic yards (162,860 cum) of a product of anaerobic digestion of sewage sludge.

There is growing demand for stabilized liquid and dried sludge for use on golf courses, park lands, sod farms, forest lands, cotton fields and lands for growth of other crops not involved in the food chain (See Section 4.6).

In any practice involving the land application of sludge materials, preliminary evaluations are needed to determine the suitability of the sludge for the soil structure at the site. Provision must be made for attenuation or diversion of surface runoff, with drainage structures, control of acidity, and monitoring of possible long-term environmental impacts (See Sections 3.8, 4, and Appendix A).

Municipal Refuse

Generation of municipal waste is largely a function of the consuming public. One of the best methods of reducing these wastes is reduction at the source, a practice that depends strongly on consumer habits. Consumers, for example, can refrain from buying vast quantities of consumable wastes, such as paper plates and nonreturnable beverage bottles and cans. Widespread and consistent use of products having longer life or potential for reuse would contribute to reduction of wastes at the source.

Although the consuming public has not taken initiative in source reduction of municipal wastes, the practice of recycling at municipal landfills or at recycling centers has gained adherents. This usually involves the physical separation of wastes into individual containers for paper (which can be separated into different grades), ferrous metals, (tin cans), non-ferrous metals, glass (separable by color) rags, tires, and large appliances. While many of these efforts have been small-scale, they tend to focus attention on resource recovery opportunities that can lead the way to large-scale source of refuse derived fuel and materials.

Large-scale recycling projects are being demonstrated in Saugus, Massachusetts, Baltimore, and St. Louis through EPA grants and under municipal auspices in Ames, Iowa and Nashville, Tennessee (Ref. III-6). These projects, include large-scale materials separators, pyrolysis units, and the consumption of shredded material for energy production by combustion. The materials separators incorporate blowers to remove paper and magnets to remove ferrous materials, while other materials are separated manually.

Waterwall incineration of municipal refuse for steam generation is becoming well-developed while pyrolysis offers a possible future energy recovery method (Ref. III-7). Pyrolysis breaks down the organic fraction of municipal wastes into simple compounds, such as gases that may be burned as fuel.

Combustion and Air Pollution Control Residuals

Resource recovery from these residuals has a longer history in Europe and Japan than in the United States but is potentially feasible here as well. Residuals from the desulfurization process, when combined with lime, fly ash and water, have potential for use as a roadbase material and a synthetic building aggregate (Ref. III-8 and Section 6.6.5).

Industrial Wastes

There is potential for recycling of resources from industrial chemical wastes. Industries presently recover scrap metals and commonly recycle solvents and other organic and inorganic compounds. Although processes are available for recycling of other industrial wastes, the economics, in many cases, do not always justify the practice.

Although Strategic Environmental Assessment Systems (SEAS) is an economic based (rather than a material balance) forecasting system, it has indicated that there is significant potential for the recovery of several metals that are in short supply (Ref. III-9). Table 3-1 shows the material recovery potential from the three industries ranking highest in the contribution of toxic substances.

Table 3-1. POTENTIAL MATERIALS RECOVERY FROM SELECTED INDUSTRIES

Industry category	Substance	(short ton x 10^3) U.S. Production[a]	(short ton x 10^3) Imports	(short ton x 10^3) Tons potentially available by recycling[c]
Blast Furnaces, Steel Works and Iron Foundaries	Chromium	0	1,450	510
	Cadmium	3.65	0.65	96
	Zinc	500	345[b]	1,050
Primary Smelting/ Refining of Non-Ferrous Metals	Lead	552	60[b]	55
	Arsenic	N/A	17.3	86
	Zinc	500	345[b]	1,135
Industrial Inorganic Chemicals	Mercury	0.684	1.03	.37
	Lead	552	60[b]	2.05

[a] 1971 data.

[b] In ore and concentrate.

[c] Totals reflect accumulated materials not presently recovered but available for recovery.

Source: Ref. III-9.

Although chromium is not produced in the U.S., about 1/3 of the chromium imports are potentially recyclable from the steel and foundries industries.

SEAS conclusion is:

> "Based upon available data, the material recovery potential from industrial residuals appears to be very great, yet it is an area only modestly explored by EPA. For reasons of environmental protection and resource recovery, as well as improvement of U.S. balance of payments, further investigations are warranted."

Recently some large-scale resource recovery plants have gone into commercial operation. These companies will consider most types of materials except perhaps radioactive wastes, pyrophoric elements, and explosive residues. The materials not recyclable are either destroyed or stored until a process is found for recycling. Typical operations include the distillation of contaminated organic and chlorinated solvents in fractionage towers. The recovered solvents are sold to chemical firms and the contaminants disposed of or converted into fuel.

For many other materials present in residuals, the economic feasibility of recovery is a major issue. For some materials, however, economic feasibility may not be far away. For example, zinc ores in the U.S. generally contain 3 to 5 percent zinc metal (Ref. III-10). Residuals from electroplating plants can contain from 10 to 40 percent zinc (Ref. III-11). Therefore, recovering zinc from electroplating residuals may be less expensive than recovering it from zinc ore. Incentive for such recovery may arise from several factors. The U.S. Bureau of Mines (Ref. III-12), estimates that only 23 years worth of zinc ore remains in the world at present rate of consumption and cost of production (obviously the supply of a material or of a suitable substitute is a major factor in determining its cost). Further, it is estimated (Ref. III-13), that the consumption of zinc by the electroplating industry alone is approximately 17,500 tons per year. On the assumption that 5 percent of the consumed zinc appears in the sludge, the annual amount recoverable is about 880 tons, which is quantitatively significant in view of the diminishing supply of zinc ores. As the supply for zinc ores diminishes, the economic incentive to recover zinc from industrial residuals will increase.

Mining Wastes

Although the research and development effort is relatively small, some work has been done on techniques for reducing and utilizing the large quantities of residual wastes from mining operations. Management practices for controlling pollution from mining operations include reclamation techniques, such as sealing to control water discharge, burying residuals, regrading to original contours, and revegetation. Other utilization techniques include use of residuals as fill in road construction and combustion of the waste to produce heat for processing (Ref. III-14).

3.3 LAND RECLAMATION

Land reclamation may be defined as the process by which productive land areas are created by the addition of foreign matter such as stabilized sludges, solid wastes, or dredge spoils. The improvements can yield aesthetic, economic, or ecological values. Successful reclamation projects include strip mine reclamation, urban expansion by filling of marginal lands, wetlands and creation of wildlife habitats by the filling of marginal land and creation of artificial islands. The planner should be cognizant of Section 404, PL 92-500 regarding permits for dredged or fill material in proposing reclamation alternatives.

3.3.1 Site Selection

Contamination of surface and ground water of reclaimed areas is possible if the soil becomes overloaded with nitrates, pathogens, or metals. The planner therefore must consider a potential site in terms of soil and substrata characteristics and climate in relation to the components and volume of wastes to be disposed of (See Section 4.1). For disposal in an aquatic environment, studies should be undertaken to evaluate all possible substratum changes, potential release of sediment and/or toxic substances to the water column, the effect of burying, turbidity, and toxic substances on indigenous benthic organisms, the effect of turbidity and toxic substances on local fish populations, and the potential of recolonization by benthic organisms (See Section 6.3).

3.3.2 Reclamation Practices

Strip Mine Reclamation

The normal operation of a strip mine leaves vast amounts of unconsolidated waste materials, known as overburden (See Section 2.8). In many areas of the country strip mines have caused major environmental problems ranging from windblown erosion in the arid west to acid mine drainage in the east. Only recently have we recognized the need to reclaim these areas. Reclamation of strip mines has been studied extensively to determine the environmental acceptability of such practices as mine sealing, contour restoration, revegetation, and sludge disposal (Ref. III-15).

In a case study at Palzo, Illinois, (Ref. III-16) significant improvements in acid drainage from the strip mine site have been achieved by addition of sewage sludge. Analysis of the drainage waters showed reductions of greater than 60 percent in aluminum and iron content and a 50 percent reduction in manganese. Concentrations of lead, copper, and sulfates also were reduced, whereas concentrations of cadmium, chromium, and zinc increased. The Palzo study indicated that the treatment of acid spoils must be at a level high enough to neutralize the spoil in order to reduce the runoff of heavy metals and maintain vegetative growth.

Problems with the release of ammonia-nitrogen and organic nitrogen often occur during the first applications of wastes to acid spoil. The Palzo study indicates that nitrification does not readily occur at low pH, and runoff can contain large concentrations of ammonia. When pH values are increased sufficiently, ammonia levels can be expected to decrease.

The moisture-holding capabilities of many organic waste residuals make them ideal as additives to soils in arid climates. Generally these soils have low organic content (Ref. III-17) and are deficient in nutrients. Addition of waste residuals can increase the erosion resistance and water holding capabilities and thus increase the potential for vegetative cover.

Marginal-Land Reclamation

Although reclamation is not their primary purpose, some sanitary landfills can be considered as land reclamation projects, since the ultimate usage of a sanitary landfill is often as park, recreation, or conservation lands.

Many land reclamation projects involving waterfront areas have wreaked havoc on marine and fresh water environments because of improper management practices. With full consideration of environmental consequences, however, such projects can be highly beneficial.

The Port of Everett, Washington, expanded its ship docking facilities with 260,000 cu yds (199,000 cubic meters) of dredge spoil. The operation involved two settling tanks, which accepted pumping from a hydraulic dredge. Almost all of the suspended matter in the slurry was settled out in the tanks, and excess water was discharged over a 200-foot skimming weir. Oil booms and sorbent material were placed at the weir to prevent the escape of oil slicks. When the cells were filled, they were allowed to dry and the dredged material was compacted and used as a foundation for further construction (Ref. III-18).

The Massachusetts Port Authority used dredge spoil material to partially fill the Bird Island Flats at Logan International Airport, Boston, Massachusetts. In this project a clamshell dragline was used to remove spoil from scows and place it within a diked area. No adverse environmental effects were reported from the disposal of 60,000 cubic yards (46,000 cubic meters) of dredge spoil (Ref. III-19).

Creation of Wildlife Habitats

When reclamation landfills are completed, the land can be deeded to a municipality and held for conservation purposes. If properly reseeded and/or reforested they could serve as local wildlife refuges or resting areas for migratory birds. In 1973 and again in 1975, two new colonies of roseate spoonbill, the only two in the United States, were found on islands created by dredged spoil material. One, an island in Tampa Bay, Florida, was created in 1931 from dredge spoil from the Alafia River; it now houses up to 25,000 birds, including spoonbills, white and brown pelicans, cormorants, egrets, herons, and ibis (Ref. III-20). The Army Corps of Engineers is investigating the possibility of creating new salt marshes which are extremely important for fish spawning (Ref. III-21).

3.3.3 Application Methods

The method of applying residuals for use in land reclamation projects is highly site-specific. Some of the more common methods are spray application, pipeline of slurries, and ocean dumping by large hopper scows.

Spray Irrigation

Spray irrigation systems have been used successfully for reclaiming strip mined areas in Illinois (Ref. III-16). In this application low-velocity nozzles are used to reduce possible air contamination by aerosols and if possible, the spray is directed downward. Spray guns are used to disperse application over a wider area where there is a possibility of ground water contamination due to high application rates.

Pipeline of Slurries

Pipelines are generally used to fill waterfront areas with dredged material. They are also being used by the Corps of Engineers in salt-marsh reclamation projects. In these cases the area must be diked to create a detention pond so that suspended solids will settle out and minimize possible water pollution.

Hopper Scows

Large hopper scows are used for aquatic disposal of residuals. They are designed so that residuals can be disposed of without causing highly turbid waters. Regarding ocean-dumping, the planner's attention is directed to Section 3.6 of this handbook as well as Section 404 of PL 92-500 and the Marine Protection, Research, and Sanctuaries Act, 1972 (40 CFR 220-227).

With any method of applying waste materials for reclamation, the management program should include the following (Ref. II-48):

1. Monitoring the accuracy of placement to prevent movement of wastes outside the area.

2. Use of large-bucket dredges or large-hopper scows to deliver spoil to the bottom in a consolidated form and thereby reduce resuspension and turbidity.

3. Covering of highly organic material or spoil containing toxic substances with relatively unpolluted materials.

4. Closing of fishing grounds during periods of dumping; these should not be reopened until the local water column has been proved free of toxic substances.

5. Maintaining of detailed records of volumes and composition of wastes applied.

3.3.4 Reclamation Use of Specific Residuals

Wastewater Sludge, Septage, Water Treatment Sludge, Feedlot Wastes

These residuals may be used for land reclamation when they are stabilized by digestion or chemical treatment prior to application. Wastewater sludge has been used to reclaim sandy soils and strip mines by converting them into valuable crop land or recreation parks. Numerous projects of this type are under way throughout the United States (Ref. III-22). Land reclamation is a satisfactory method of sludge disposal to the extent that it is relatively economical, and it recycles the organic content of the sludge for beneficial purposes.

Dredge Spoil

As discussed earlier, land reclamation with dredged material has been highly successful, however, careful management is critical. For example, in salt marsh reclamation projects only unpolluted spoil without the possibility of serious damage to the estuarine environment may be used. Unconsolidated silt should not be used for foundation materials in reclamation projects because of its instability.

3.4 LAND SPREADING

The practice of spreading waste residuals onto agricultural land has been used on a limited basis for decades. This practice provides the advantages of economy and the recycling of nutrients, water, and organic matter. Although land spreading is a safe method of disposal if properly managed, the possible negative effects include contamination of surface and ground waters, accelerated eutrophication of streams and ponds, and accumulation of toxic metals in soils and vegetation.

3.4.1 Environmental Considerations

Nitrogen

Possible contamination of surface and ground water by nitrate-nitrogen as well as other substances plays a significant role in determining the maximum allowable application rates of waste residuals to soils. The acceptable application rate is a function of the sludge's nitrogen content and state (ammonia or organic), type of vegetation, crop yield, soil, and climate. Nitrate contamination becomes a problem only when the application rate exceeds the nitrogen uptake by plants and losses of gaseous nitrogen to the atmosphere (Ref. III-23).

It is often recommended, as a rule of thumb, that the nitrogen application rate not exceed 2 times the crop intake of nitrogen. A more precise guideline should be applied for large-scale projects (Ref. III-24). The rate of movement of soil nitrate is estimated by applying different concentrations of fertilizer to test plots and measuring the leachability through the soil to depths of 35 and 47 inches (90 and 120 cm). This procedure would involve a 2-year study, because nitrates cannot reach these depths in 1 year. When land spreading operations begin, the soil water should be monitored to determine whether application rates must be adjusted to keep the nitrate concentrations in ground water below the limits set by the U.S. Public Health Service for drinking water. It has been shown that the accumulated organic nitrogen in the soil will eventually buildup and become a major source of nitrogen available for plants. As a result, moderation in sludge application rates should be exercised to prevent accumulation of toxic levels of nitrogen (Ref. III-23).

Pathogens

The typical microflora of many waste residuals may contain enteric or pathogenic organisms with which workers may come in contact. It is emphasized, however, that only one outbreak of disease has ever been attributed to land application of sewage or sludge (Ref. III-25). There is also a possibility that surface waters may be contaminated by runoff from disposal sites. Contamination of ground water usually is minimal because of the filtering characteristics of soil, although that filtering efficiency decreases with time.

Metals

Land application of waste residuals containing large amounts of metals can entail many potential problems. The interactions of metals with soils are extremely complex. Certain metals such as copper, molybdenum, and zinc are plant micronutrients, whereas others such as cadmium, chromium, and mercury have no known beneficial function in plants.

Metals such as zinc, nickel, and cadmium can cause plant toxicities. Perhaps the greatest concern is directed toward the cadmium content of sludges, since the accumulation of cadmium in plant tissue can result in significant transfer to higher animals (See Section 4.6).

In view of the potential toxicity of certain heavy metals to plants, animals, and human beings, the metals content of sludges for land application must be closely monitored (See Appendix A). Location of land areas for receipt of metals-containing sludges should be carefully identified and recorded. Finally, programs for pretreatment to remove toxics should be considered (See Page C-3).

Site Selection

As in selection of sites for other disposal methods, the soil characteristics, climate, and residual components and volume are the variables that most strongly determine acceptability for land application. If the residual contains relatively low amounts of heavy metals, it may be applied to agricultural lands, under some conditions, although not to lands used for food production (See Page C-1). Residuals with high metals content could be applied to sod farms, parks, golf courses, forests, highway median strips, or land reclamation projects if precautions are taken to prevent runoff to surface waters or contamination of ground waters (See Section 4).

3.4.2 Preparation of Residuals for Land Application

Prior to land application all waste residuals should be stabilized or chemically treated to reduce public health hazards and odors. This can be accomplished by a number of methods.

Anaerobic Digestion

Properly designed and operated anaerobic digesters can reduce influent coliform bacteria by 97 percent or more (Ref. III-26). Pathogens usually are reduced significantly but some may persist, such as Ascaris ova and Entamoeba Histolitica cysts. Odor control is attained by volatilization or organic matter.

Because anaerobic digestion can decompose more organic matter per unit volume than an aerobic process, anaerobic lagoons are often considered for initial stabilization of strong (high BOD) organic wastes. BOD_5 conversion efficiencies up to 70 percent are obtainable routinely. Proper loading rates are critical to a soundly functioning lagoon.

The most serious environmental threat from lagooning is the escape of liquids by percolation or overflow. Percolation can be avoided by locating lagoons over impervious soils, where bottom and sidewalls can be made impervious. Lagoons constructed on highly permeable soils

require sealing with liners, clay, or soil cement. Sealing can be partially biological (animal waste solids provide a good sealant in many soils) but time is required for such materials to form a good seal. Runoff and overflow from lagoons are controlled by constructing dikes, diversion channels, or terraces.

Aerobic Digestion

In an aerobic treatment system, biological oxidation converts organic matter (mostly manure) to carbon dioxide, water, and microbe cells. Oxygen must be supplied either naturally or artifically to maintain an aerobic system.

Aerobic systems are considered feasible when the rate of oxygen transfer to the waste stream has no upper limits. BOD reductions of 50 percent can be expected if the system design provides for complete aeration with sufficient detention time.

Aerobic oxidation can be achieved in shallow lagoons or ponds (3 to 5 feet deep) with large surface areas to accomodate aeration. The biochemical reactions occurring in ponds and lagoons are not strictly aerobic. As sludges and solids accumulate at the bottoms, some anaerobic activities can be expected.

Design criteria for ponds range from 20 to 40 pounds of BOD per acre per day, (22 to 45 Kg per ha per day) depending on geographic location (Ref. III-23). On the basis of the top of this range (40 pounds (18 kg) per acre per day), one can estimate the size of ponds required for aerobic digestion of residuals, using feedlot wastes as an example. A confined feedlot for 1,000 head of beef cattle averaging 1,000 pounds (454 kg) of weight per head required approximately 40 acres (16 ha) of pond to achieve aerobic digestion (See Section 2.7). Requirements for wastes from other animals on a nonequivalent basis, are proportionately lower:

- 1,000 hogs require 7.5 acres (3 ha).
- 100 dairy cows require 6 acres (2.4 ha).
- 50,000 broilers require 3 acres (1.2 ha).

Thus, aerobic treatment systems require large areas of land for ponds and lagoons, which sometimes must also be lined to retard the migration of hazardous pollutants. In addition, these ponds should be bounded with structures to control runoff such as dikes, diversion channels, terraces or culverts. Finally, the ponds should be fenced to prevent health and safety problems caused by easy access.

The sizes of ponds and lagoons can be reduced by designing and installing mechanical systems for aeration (floating, vertical-shaft aerators).

Long-term Storage

Long-term storage is the simplest method of reducing pathogens. A period of 60 days at 20C or 120 days at 4C normally kills most microorganisms (Ref. III-26). Volatilization of organics over this period will also significantly reduce odors.

Following are some guidelines for design of a waste storage facility.

- Do not locate storages on creviced bedrock, gravel, permeable soil, or below the water table.
- Allow at least 100 fect (30 meters), between a water supply and the nearest part of a storage facility.
- Shield storages from public roads and family living areas.
- Consider prevailing winds.
- Plan the location, size, and design of storage for year-round use.
- Check with local environmental agencies and health officials for assessment or regulatory requirements before construction begins.

Storage facilities include storage gutters, below-ground tanks, silos, earth solid manure facilities, earth liquid and slurry systems, and holding ponds.

Chemical Treatment

Lime treatment (to raise the pH above 12), disinfection by chlorination, or heat treatment of sludge also effectively reduce pathogens. Although the organic matter is not volatilized, odors are controlled because release of gases after spreading is slow.

3.4.3 Application Methods

Some sludges can be applied to soil by several techniques which are highly dependent on its water or solids content.

Spray Irrigation

Spray irrigation of liquid digested sludge can be done only with slurries of low solids content and with high-pressure sprayers to prevent clogging. Mobile irrigation equipment such as the "rain gun" spray nozzle provides operational flexibility and can be used in inclement weather (Ref. III-27).

Ridge and Furrow

The ridge and furrow method of sludge application is economical and effective. The sludge flows into furrows, where the liquid portion infiltrates the soil. After solids have built up in the furrows, the sludge is incorporated into the soil by plowing.

Plow-Furrow-Cover

This method, using a 16-inch (41 cm) single-bottom moldboard plow, is highly adaptable to most soil conditions. A slurry of up to 25 percent solids is deposited in a plowed furrow 6 to 8 inches (15 to 20 cm) deep. Immediately after deposition, in the same operation, the plow covers the waste and opens the next furrow. Approximately 1 to 2 inches (2.5 to 5.08 cm) (170-225 tons per acre) (154 to 204 metric tons) can be completely covered. This equipment operates at 3 mph (4.8 km/hr) and can unload up to 200 gallons (.76 cu meters) per minute. After application the soil is ready for disking and seeding (Ref. III-28).

Plow Injection

Plow injection is another highly adaptable method. The sludge is pumped through a flexible hose attached to a tractor. A spreader plate applies the sludge to the soil just in front of a plow and disk which incorporate the sludge into the soil (Ref. III-28).

Sub-Soil Injection

A popular subsurface applicator, features a knife design that opens and closes any tillable soil to a depth of 6 to 8 inches (15 to 20 cm), while injecting material at a rate of 600 to 800 gallons (2.3 to 3.0 cu. meters) per minute at speeds up to 6 miles per hour (9.6 km/hr) (Ref. III-29).

Truck Application

One of the easiest methods of application of liquid wastes is direct dumping in the field with trucks. Wet weather conditions can be overcome by use of specially-wheeled vehicles commercially available. A deflector plate may be used or the truck may be fitted with a pumping unit and spray nozzle to allow uniform application.

Manure Spreaders

Manure spreaders have been used for decades for spreading animal wastes on farmland. Equipment for dispersing sludge cakes of greater than 25 percent solids has been field tested at the New Jersey Agricultural Station. One such spreader can be adjusted for surface spreading or converted to convey waste into a furrow (Ref. III-28).

Typical costs of dry land spreading and truck transport are given in Tables 3-2 and 3-3. A further indication of total costs for land application of septage residuals is given below. These are as reported by Johnson (Ref. III-30) regarding handling of septage from 40,000 persons whose septic tanks are pumped once every 5 years. All three include an amortized cost of soil injector, which sells for about $35,000 (1976).

1. Covered receiving tank
   Lime stabilization
   Diffused aeration
   Soil injection
   Total annual cost - $31,000 ($13/1000 gal. ($13/3.8 cu. meters), $52/dry ton ($57/metric ton))

2. Covered receiving tank
   Diffused aeration
   Soil injection
   Total annual cost - $24,000 ($10/1000 gal. ($10/3.8 cu. meters), $40/dry ton ($44/metric ton))

3. Covered receiving tank
   Soil injection
   Total annual cost - $16,500 ($7/1000 gal. ($7/3.8 cu. meters), $28/dry ton ($31/metric ton))

3.4.4 Management Practices

Loading Rates

In terms of sludge deposition, nitrogen loading should not exceed the sum of the losses through volatilization, denitrification, and plant uptake, with a modest loss to ground water. Where higher volatilization rates are desired, the wastes should not be plowed into the soil immediately. In this case measures should be taken to control surface runoff.

Stabilization-Conditioning

All residuals to be land applied should be stabilized, conditioned, or chemically treated before application to reduce pathogens and control odors.

Monitoring

In order to be alert to possible contamination of surface and ground water, all lands used for waste residual application should be routinely monitored to ascertain the movement of nitrates, persistent organics, pathogens, and metals (See Appendix A).

Table 3-2. TYPICAL DRY LAND SPREADING COSTS

Tons/day	Tons/year	Expenditure[a]	Amoritized capital cost[b]	Annual amortized capital	Annual O&M[c]	Total annual cost	Unit cost/ton
100	31,200	61,200	122,862	6,143	36,018	42,161	1.35
200	62,400	122,400	245,724	12,286	72,036	84,322	1.35
300	93,600	163,200	327,632	16,382	107,488	123,870	1.32
400	124,800	224,400	450,494	22,525	143,506	166,031	1.33
500	156,000	285,600	573,356	28,663	179,524	208,192	1.33
600	187,200	346,800	696,218	34,811	215,542	250,353	1.34
1000	312,000	571,200	1,145,712	57,336	359,048	416,384	1.33

[a] Includes cost of tractors, spreaders, and loaders. All costs adjusted to reflect 1976 dollars.

[b] Amortized at 8% over 20 years level debt service.

[c] Includes salaries, fuel, equipment maintenance and replacement.

Source: Ref. III-31

Table 3-3. TYPICAL SOLIDS TRUCK TRANSPORT COSTS

Truck capacity tons	Tons/year[a]	Expenditure	Amoritized[b] capital cost	Annual amortized capital	Annual O&M[c]	Total annual[d] cost	Unit cost/ton
7	14,560	44,800	54,500	2,725	39,900	42,625	2.92
10	20,800	112,000	136,300	6,815	48,250	55,065	2.65
15	31,200	135,300	164,500	8,225	50,050	58,275	1.87
20	41,600	140,000	170,300	8,515	52,000	60,515	1.45

[a] Tonnage computed at 8 roundtrips per day, 260 days per year.

[b] Cost amortized at 8% over 5 year term, level debt service. Cost presented represent the 20 year cost that will be incurred.

[c] Costs include labor, fuel, insurance, and maintenance of vehicles.

[d] Based on 8 roundtrips per day, 30 miles per roundtrip, 260 days per year.

Source: Ref. III-31

Records

Accurate detailed records of sludge characteristics and application rates should be maintained. These records should include data from monitoring programs. This information will aid research and more significantly, will enable the user to project future loadings rates accurately and provide a basis for levying fees.

3.4.5 Land Spreading of Specific Residuals

Sewage sludge, feedlot wastes, and septage may be safely land spread by the management practices described earlier, including analysis of the residuals for nitrogen and metals contents treatment to reduce microorganisms and offensive odors, careful application, and detailed record keeping. No adverse effects have been reported from direct disposal of septage on land at a rate equivalent to 300 pounds of nitrogen per acre (336 kg/ha) (Ref. III-32). These applications were done by ridge-furrow-cover, surface soil injection and sub-sod injection.

Land application of feedlot wastes is increasingly popular because it improves the soil texture, increases capacity for water retention, reduces erosion, and promotes the population of beneficial soil microorganisms. As confinement feeding of livestock increases, however, the problems entailed in seasonal disposal of the wastes may require installation of processing facilities at the feedlots.

Dredge spoil has been used, on a limited basis as a soil amendment (Ref. III-33). Generally only spoil from fresh water operations can be used because of the high salt content in marine dredge spoil. Here again the spoil should be analyzed for nitrogen and metal contents as well as other toxics (See Appendix B).

3.5 SANITARY LANDFILL

A sanitary landfill is defined by the American Society of Civil Engineers and later refined by EPA includes the following concepts:

> A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary (Ref. III-34).

The EPA has published (Ref. III-35), general requirements for operation of a sanitary landfill:

1. Wastes for which the specific facility has been designed to hold are the only ones to be accepted -- usually bulky wastes, digested and dewatered sludge, and septic tank pumpings.

2. If the facility is designed to handle special wastes, they should be placed in special areas and marked.

3. Certain hazardous wastes should be excluded from municipal landfills -- toxic chemicals (e.g. PCB's, pesticides, radioactive wastes, heavy metals, or any other which may contribute to ground water contamination).

4. All waters discharged from the facility shall be sufficiently treated to meet the most stringent of applicable water quality standards in Federal Water Pollution Act.

5. Effluent waters should not be discharged indiscriminantly. Where this is not done discharge should be monitored and means to control excessive contamination should be available.

In addition to these general requirements, this section presents detailed guidelines for the siting, design, and operation of a sanitary landfill.

3.5.1 Site Selection

The design of a sanitary landfill is site specific and dependent on the hydrogeology, soils, topography, and climate of the area and on the type and quantity of wastes to be handled.

The volume requirement of a sanitary landfill is site specific and should be determined on the basis of the estimated amount and type of solid wastes to be disposed. The volume requirement can be calculated roughly from estimated values of 5.3 lb/person/day (2.4 kg/person/day), density of 500 lb/yd^3 (297 kg/m^3) and one part earth cover to four parts waste (Ref. III-36).

The site must be readily accessible to trucks that transport and dump the wastes. It should be located in a nonresidential area to minimize complaints regarding heavy truck and automobile usage, odor, and blowing debris.

One of the most important aspects of site selection is the potential of ground water and surface water contamination. The primary consideration here is hydrogeology of the site, which is a major factor in leachate formation and resulting water pollution problems. In some cases, leachate has been collected for treatment in municipal wastewater plants prior to discharge (Ref. III-37).

Generally, the site should be located in an area in which the water table is more than 5 feet (1.5 m) below the bottom of the cells. The topography should be flat enough that runoff cannot contaminate surface waters. The sub-surface soils should be of low permeability with no joints or fractures. Such soils reduce movement of leachates and provide some protection against ground water contamination.

3.5.2 Application Methods

Surface Water Control

Surface runoff should be diverted from the landfill site by use of pipes, drainage ditches, or dikes. In cases where surface water runoff contains a heavy load of suspended solids, a detention pond is recommended to settle out the solids prior to discharge to water courses.

Ground Water Protection

Leachate formation in landfills can lead to pollution of water resources. Nutrient overenrichment of surface and ground waters, and bacterial and chemical contamination of drinking water supplies are but a few of the primary effects of leachate entering water courses. In arid and semiarid areas where evapotranspiration exceeds annual precipitation, leachate formation is generally negligible. A leachate control system usually is not required in such areas unless wastes with high water (liquid) content are deposited.

In areas where precipitation equals or exceeds evapotranspiration, some type of leachate control system is required. Control may take the form of impermeable liners (bottom and/or top) or a subsurface collection system. In either case, the leachate must be treated before release to the environment.

Liners

A recently developed technique for aiding in the elimination of leachate problems is installation of an impervious cell liner. The liner can be made of asphalt, cement, compacted clay, treated soils, or any number of polymeric materials, such as polyvinyl chloride or polyethylene. All of these materials have been used as liners at one or more landfill sites (Ref. III-38).

The use of liners involves two problems. First, rigorous construction standards must be observed to assure proper sealing of the cell. Second, problems could arise from leaks if the leachate reacts with the liner. The long-term effects of leachate on the aforementioned liners is not well known, although some problems have been documented. For example, polyvinyl chloride and polyethylene are susceptible to degradation from sunlight and ozone, butyl rubber and ethylene-propylene diene monomer are not resistant to hydrocarbons and organic solvents, and a clay-treated soil, requires the addition of special polymers when contacting dissolved salt concentrations exceeding 1000 ppm (Ref. III-38).

With flexible liners such as PVC or polyethylene, 1 to 2 feet (.3 to .6 m), of soil should be placed over the liner to protect it from punctures during compaction or initial filling (See Table 3-10). If the liner is not covered with soil, precautions should be taken to protect it from materials with jagged edges; no vehicles with crawler tracks should be used in the cell until a sufficiently thick base has been deposited.

Underdrains

Because of the uncertainty of liner effectiveness, in practically all of the landfills requiring membrane liners and sealant additives some method of underdrain catchment of generated leachates is required to insure against excess ground water contamination from the disposal area. Two especially descriptive discussions on this subject are contained in recent works (Ref. III-39,40).

If the landfill is always above the top of the zone of saturation, a closely-spaced system of interconnected tile or gravel-filled ditch underdrains may be necessary. If total leachate collection is essential, the drain system must be bedded in permeable material such as sand and gravel and underlain by an impermeable liner. In this type of underdrain system, some method for removal of the contaminated fluid must be provided. If a natural ravine or hollow underlies the landfill, the installed drainage system can be designed to divert all fluids collected into a main collector tile laid along the base of this topographic low and directed from there to some downgradient removal point near the downstream end of the filled area as is shown in Figure 3-1. The accumulated fluids in a bowl-shaped liner can be diverted by the tile drainage system to the center low and collected there in a specially designed sump for pump removal (see Figure 3-1). The effectiveness and efficiency of either of these types of underdrain systems located above the water table depends primarily upon the placement and spacing of the drains and the permeability of their bed material. In such systems, care must always be taken to insure that appreciable quantities of the leachates generated in the fill area will not move below the effective reach of the installed drains. If this is not done, the uncaptured liquid can readily migrate further downward, perhaps to cause serious water-quality degradation in underlying ground water reservoirs.

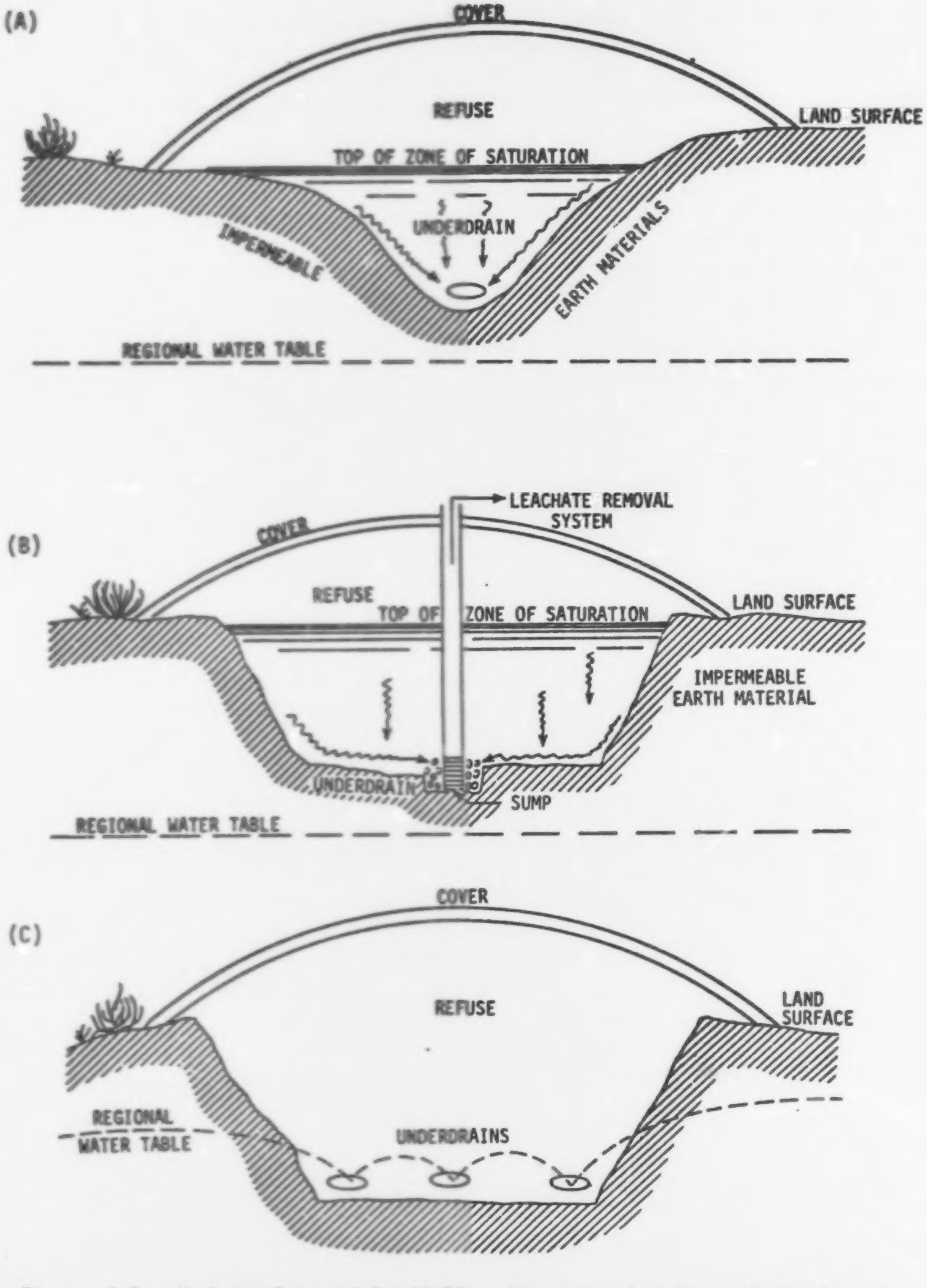
(A)
COVER
REFUSE
LAND SURFACE
TOP OF ZONE OF SATURATION
UNDERDRAIN
IMPERMEABLE
EARTH MATERIALS
REGIONAL WATER TABLE
(B)
LEACHATE REMOVAL SYSTEM
COVER
REFUSE
TOP OF ZONE OF SATURATION
LAND SURFACE
IMPERMEABLE EARTH MATERIAL
UNDERDRAIN
SUMP
REGIONAL WATER TABLE
(C)
COVER
REFUSE
LAND SURFACE
REGIONAL WATER TABLE
UNDERDRAINS

Figure 3-1. Hydrogeology of landfills with ways of using underdrains to control leachate migration. (A), above watertable in topographic low; (B) above watertable where underdrain sump-tile laid collection is required; and (C) below the zone saturation.

If the landfill excavation extends below the water table and is finished within the zone of saturation as is illustrated in Figure 3-1, a system of underdrains can be installed near the bottom, or just below the fill excavation, to capture any ground water that normally would enter the landfill from the sides or below. By creating an inflow hydraulic gradient of this type, movement of leachate out of the site is practically eliminated. In such systems, it is essential to always keep the level of the collector systems' outlet below the elevation of its laterals so that a continuous flow is maintained to the outlet point. Only by so doing can an inflowing ground water gradient be assured. In this regard, as the volume of flow to the collection point is basically controlled by the elevation differential, it follows that the lower the outlet or sump-pump setting, the greater will be the leachate ground water flow to the collection point. From a leachate-treatment cost standpoint, this fact is especially significant for both the gravity and sump-pump underdrain systems, because after leachates are collected, they have to be treated; and the greater the volume of leachates collected, the higher will be the total cost of treatment (See Section 4.4).

Grouting

Grouting is the process of pumping fluid pastes through small-diameter holes into pervious materials. The line of holes is so spaced that the grout material introduced into each hole (ideally) meets the material pumped in on either side. The resultant barrier, formed when the paste sets, is known as a grout curtain. The procedure is widely used for tightening dam foundations.

The use of a grout curtain to eliminate or reduce the migration of contaminated ground water from a disposal area is subject to the same basic restriction that applies to other methods of physical interception; there must be no chance for the contaminant to pass around the ends of the intercepting system. Grouting will be applicable only to cases where the section of contaminant flow is relatively restricted.

Generally, the only case in which grouting can be used without the additional use of pump-back wells is beneath the dike of a pond. Otherwise, the curtain, if it is at all effective, will act as a ground water dam, and if pumps are not installed upstream from it the ground water will rise and eventually appear as surface flow.

The use of grout in cases where an absolute cutoff of contaminant flow is required (as from industrial waste ponds) is generally impracticable, since it is usually impossible to create a completely impervious curtain. The aquifer may consist of unconsolidated material, fractured rock, or a combination of the two. In the presence of fractured rock, it is difficult to ensure that the entire fracture zone has been penetrated; with fine-grained unconsolidated sediments the penetration of conventional grouting material (Portland cement) is inadequate. Proprietary chemical grouts, such as AM-9 (acrylamide methylene bisacrylamide) will penetrate much smaller pores than will cement, but they are quite expensive and there is still no assurance of 100 percent effectiveness. Other grouts, such as bituminous emulsions and silicate solutions, may prove both economic and offer similar penetrating ability. The importance of the degree of effectiveness is illustrated by the fact that to achieve a 90 percent reduction of permeability in the grouted zone, more than 99 percent of the cracks or pores must be grouted (Ref. III-41). Where there are large fractures or solution channels, especially with relatively rapid ground water flow, grouting may be impossible.

For cases where only a reduction in contaminant leachate is required, and where sub-surface conditions are favorable, grouting may be a satisfactory solution. One problem is that the effectiveness of the curtain generally cannot be determined until the grouting has been completed.

Other Leachate Control Measures

During operation of a landfill, a number of other methods can be employed to control leachate. One is the addition of sand, fly ash, or other material to absorb and neutralize some of the leachate until saturation is reached. A major factor in reducing leachate production is the daily and final cover material or plastic liner. The daily cover material should consist of a compacted relatively impermeable soil that will allow precipitation to run off the working face of the cell. Final cover material should also be impermeable. In regions where clayey soils for lining are scarce or not available, plastic liners covered with a minimum of 2 feet (.6 meters) of soil can be used.

Gas Control

Decomposition of solid wastes can produce gases, generally methane, which is explosive in concentrations greater than 5 percent and carbon dioxide. It can also produce other gases such as hydrogen sulfide, which is malodorus, toxic, combustible, and explosive (Ref. III-39). These gases usually pose no problems when they can disperse into the atmosphere. If an impermeable cover material is used, however, gases must be vented to the atmosphere by means of vent pipes or permeable sand or gravel vents.

Monitoring Systems

Landfill operators should provide a series of observation wells to monitor ground water quality. Upstream and downstream measurements should be compared to evaluate any pollution problems (See Appendix A).

3.5.3 Management Practices

Improper management can reduce the effectiveness of the best-designed sanitary landfill. The consequences may be minor, such as blowing litter or bad odors, or may entail major and extremely serious problems. Liners can be destroyed by the addition of unauthorized chemicals. In one instance an operator was killed in a municipal landfill when his bulldozer ran over a 55-gallon (.2 m^3) drum containing volatile industrial wastes.

Detailed records of incoming waste material are required for evaluating the landfill operation and planning future uses and/or expansion. The records should include type, weight, and origin of the materials. This information can then be used to determine compaction and operation efficiency and to estimate the amount of decomposition and eventual settling. Cost accounting records also are required for budgetary planning and evaluation.

Any industrial or other potentially hazardous wastes must be inventoried and their location in the landfill clearly identified so that the materials can be removed in the future if pollution problems should occur.

Operational Methods

Operation of a sanitary landfill consists of three basic steps after wastes have been added: spreading, compaction, and covering.

After wastes have been dumped they must be spread onto the working face of the landfill. As wastes are spread, the operator should ensure that they are thoroughly mixed to facilitate uniform settling.

Compacting the wastes reduces the total volume of the wastes and also reduces the potential for blowing litter.

Covering of wastes at the end of the working day can prevent or reduce blowing litter, formation of odors, and use of the area by wildlife. A minimum daily cover of 6 inches (15 cm) of compacted soil having good compaction characteristics is recommended to conserve land and help prevent subsidence. The cover should be graded to direct runoff from the site. If the cell is not to have an additional lift added for 1 year, 12 inches of compacted cover material are recommended. Final cover should consist of 2 feet (.6 meters) of soil and be revegetated (Ref. III-36).

Completed Landfill

When the landfill is completed, maintenance of the site usually involves regrading and filling of small depressions that result from uneven settlement. This must be done to maintain good drainage of the area and prevent excessive generation of leachate. Typical costs for landfilling are presented in Table 3-4.

3.5.4 Disposal by Landfilling of Specific Residuals

Sewage Sludge, Septage, and Water Treatment Sludge

Many sanitary landfills accept sewage sludge and/or septage but do not properly protect the environment from pathogenic organisms and possible toxic compounds in these wastes that might leach into ground water.

It is recommended that sewage sludge and septage be dewatered and stabilized (digested) before they are added to the landfill. Dewatering by such means as centrifugation or vacuum filtration can reduce the moisture content of sludges to 50 percent although typical costs effective methods will not exceed 25 percent solids. The combined solid wastes and sludge should be thoroughly mixed and covered immediately to control odors and to prevent contact with vectors such as flies and mosquitoes.

Combustion Air Pollution Controls and Incineration Residues

The residuals in this category are mainly sulfur oxides sludges from fossil fuel power plants; a highly variable inorganic residue from municipal incinerators and sludge treatment plants; and fly ash from pollution control devices. All of these can be disposed of in a sanitary landfill. Fly ash is often useful because of its moisture absorbing characteristics.

Municipal Refuse

Landfill is the method most commonly used for ultimate disposal of municipal refuse. Prior to disposal, municipal refuse may be processed to obtain some type of beneficiation or reduction in volume. Following is a brief list of processing methods and combinations thereof that are commonly used in preparing municipal refuse before landfill. The list is not exhaustive, since other methods are available and may be appropriate for specific applications (Ref. II-23, III-42,43).

A) Shredding → Material Separation → Combustion in Industrial Boiler → Ash Lagooning → Landfill Ash

B) Incineration → Ash Lagoon → Landfill Ash

C) Shredding → Landfill

D) Baling and Compacting → Landfill

Table 3-4. TYPICAL LANDFILLING COSTS

Tons/day	.Tons/year[a]	Estimated Costs[b]					
		Expenditure[c]	Amoritized[d] capital cost	Annual amor-tized capital	Annual O&M[e]	Total annual cost	Unit[f] cost/ton
100	31,200	1,077,115	2,161,682	108,084	180,600	288,64	9.25
200	62,400	1,145,964	2,300,422	115,021	191,520	306,541	4.91
300	93,600	1,556,145	3,124,444	156,222	240,504	396,725	4.24
400	124,800	2,007,398	4,031,426	201,571	283,872	485,443	3.89
500	156,000	2,383,621	4,787,007	239,350	327,240	566,590	3.63
600	187,200	2,762,964	5,548,922	277,446	366,864	644,310	3.44
1000	321,000	4,244,287	8,524,227	426,211	525,360	951,571	3.05

[a] Based on 312 days/year, 6 days/week, 8 hours/day.

[b] All costs adjusted to represent constant 1976 dollars (i.e., 1976 = 100).

[c] Based on in-situ compacted density of 800 lbs/yd^3, 12 feet operating depth, and site efficiency of 85% (6582 tons/acre). Includes site work, scales, roads, fences, structures, materials, installation, surface surveys, subsurface investigations, operating equipment, constractors' overhead, clay liner, monitoring wells, and profit, etc. Does not include engineering and legal fees, contingencies, resource recovery, collection, land cost, and haul to the landfill, etc.

[d] Amortized at 8% interest, 20 year term, level debt service.

[e] Includes salaries and overhead, fuel, utilities, equipment maintenance and replacement, etc. Does not include collection and haul to the landfill, etc.

[f] No credit given for ultimate sale of completed sanitary landfill land after 20 years.

Source: Ref. II-23

The typical costs presented in this section are not site-specific; they should be regarded only as order-of-magnitude indicators.

Shredding, Material Separation, Combustion in Industrial Boilers, Ash Lagoon, Landfill of Bottom Ash from Lagoon

Shredding and separation are means of breaking down relatively large materials into smaller particles to produce a more homogenous product from which the combustible and noncombustible fractions are separated, as shown in Figure 3-2. Noncombustible fractions can be sold if a market is available, and combustible fractions can be fired in industrial boilers as a supplemental fuel. Table 3-5 lists typical costs for such an operation.

Incineration, Ash Lagoon, Landfill

Although the practice of incineration is severely criticized on environmental and economic grounds, it remains a viable alternative in heavily urbanized areas or in areas where land is at a premium. Incineration reduces the volume of solid wastes by one-half or more, prior to ultimate disposal. The lagoons are used merely as thickening basins for slurried ash from the incinerators. The ash is periodically taken from the lagoon to a landfill for ultimate disposal. Table 3-6 depicts typical costs for such a process.

Shredding, Landfill

Shredding of municipal refuse and subsequent landfilling is a process adaptable to areas with large volumes of municipal refuse and limited area for landfilling. Shredded municipal refuse lends itself to a higher degree of compaction (approximately 25%) at the landfill thus resulting in 25 percent less land required to landfill the refuse than if it were not shredded. The planner needs to analyze the possible land savings as an offset to the high cost of shredding. Table 3-7 lists typical costs for this process.

Baling and Compacting and Landfill

Widely used for many years in industry and agriculture, baling is a simple form of packaging. The baling and compacting of municipal refuse reduces the volume of refuse, extends the life of the landfill and, with proper equipment, facilitates handling. Cost of baling municipal refuse is relatively high, however, and the method may be considered only in situations where offsetting cost benefits from land use, handling, or transportation can be realized. Table 3-8 gives estimated costs of baling and compacting operations.

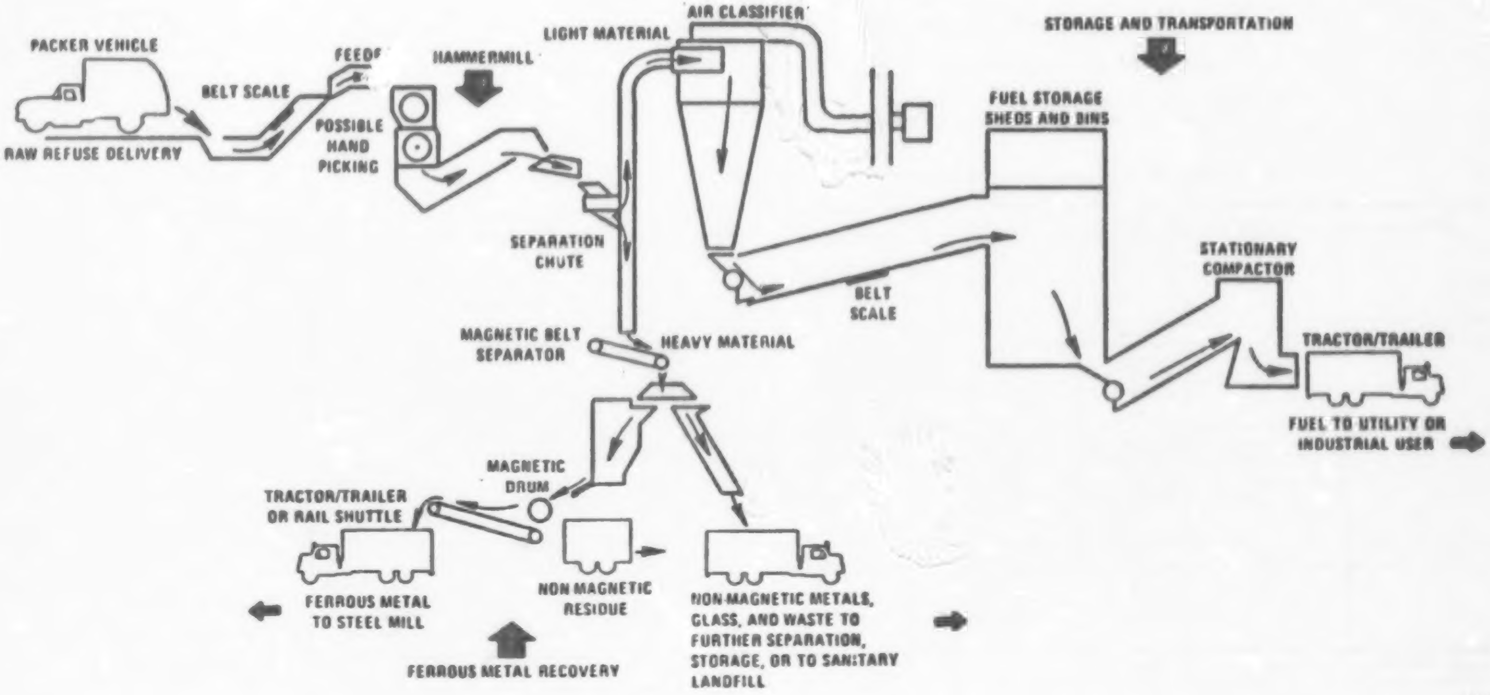
PACKER VEHICLE
RAW REFUSE DELIVERY
BELT SCALE
FEEDER
POSSIBLE HAND PICKING
HAMMERMILL
SEPARATION CHUTE
LIGHT MATERIAL
AIR CLASSIFIER
STORAGE AND TRANSPORTATION
FUEL STORAGE SHEDS AND BINS
BELT SCALE
STATIONARY COMPACTOR
TRACTOR/TRAILER
FUEL TO UTILITY OR INDUSTRIAL USER
MAGNETIC BELT SEPARATOR
HEAVY MATERIAL
MAGNETIC DRUM
TRACTOR/TRAILER OR RAIL SHUTTLE
FERROUS METAL TO STEEL MILL
NON MAGNETIC RESIDUE
NON-MAGNETIC METALS, GLASS, AND WASTE TO FURTHER SEPARATION, STORAGE, OR TO SANITARY LANDFILL
FERROUS METAL RECOVERY

Figure 3-2. Shredding and material separation process.

Table 3-5. ESTIMATED COSTS OF SHREDDING AND MATERIAL SEPARATION, AND LAGOONING AND LANDFILLING OF ASH FROM COMBUSTION IN AN INDUSTRIAL BOILER

			Estimated costs[a]				
Input tons/day[b]	Process	Expenditure[c] $1,000	Amortized[d] capital cost $1,000	Annual amortized capital $1,000	Annual O & M[e] $1,000	Total annual cost $1,000	Total cost/ input ton
100	Shredding and material separation	2,017	4,077	204.0	207.0	411.0	
	Ash lagoon	39	78	3.9	11.3	15.2	
	Landfill	436	876	43.8	73.2	117.0	
	Total	2,492	5,031	251.7	291.5	543.2	20.89
200	Shredding and material separation	3,447	6,919	346.0	344.0	690.0	
	Ash lagoon	78	156	7.8	22.5	30.3	
	Landfill	727	1,460	73.0	122.0	195.0	
	Total	4,252	8,535	426.8	488.5	915.3	17.60
400	Shredding and material separation	3,320	6,663	333.0	399.0	732.0	
	Ash lagoon	155	312	15.6	45.1	60.7	
	Landfill	1,030	2,068	103.4	172.7	276.1	
	Total	4,505	9,043	452.0	616.8	968.8	9.32
1,000	Shredding and material separation	8,000	16,061	803.0	1,100.0	1,903.0	
	Ash lagoon	388	780	39.0	112.7	151.7	
	Landfill	1,447	2,906	145.3	242.8	388.1	
	Total	9,835	19,747	987.3	1,455.5	2,442.8	9.40

[a] All costs adjusted to represent 1976 dollars. Recovery from sale of secondary material and combustible fraction not included.

[b] Based on 260 days/year, 5 days/week, 8 hours/day.

[c] Includes site work, mechanical equipment, scales, roads, fences, structures, materials, clay liners, installation, contractor's overhead, and profit, etc. Does not include special foundations, engineering, and legal fees, contingencies, rolling stock, etc.

[d] Amortized at 8% interest, level debt service, 20-year term (ash lagoon and landfill), 15 year term (shredders). All costs, however, represent a 20-year cost.

[e] Includes salaries and overhead, fuel, utilities, equipment maintenance and replacement, etc.

Source: Ref. II-23, III-44, 45, 46

Table 3-6. ESTIMATED COSTS OF INCINERATION OF MUNICIPAL REFUSE AND DISPOSAL OF THE RESULTANT ASH

Input tons/day[b]	Process	Expenditure[c] $1,000	Estimated costs[a] Amortized[d] capital cost $1,000	Annual amortized capital $1,000	Annual O & M[e] $1,000	Total annual cost $1,000	Total cost/ input ton
100	Incineration	2,719	5,459	273.0	373.0	646.0	
	Ash lagoon	34	69	3.5	10.4	13.9	
	Landfill	509	1,022	51.1	85.4	136.5	
	Total	3,262	6,550	327.6	468.8	796.4	30.63
200	Incineration	3,499	7,026	351.0	594.0	945.0	
	Ash lagoon	69	138	4.2	12.5	16.7	
	Landfill	763	1,531	76.6	127.9	204.5	
	Total	4,331	8,695	431.8	734.4	1,166.2	22.08
400	Incineration	4,006	8,045	402.0	861.0	1,263.0	
	Ash lagoon	138	277	8.3	25.0	33.3	
	Landfill	944	1,697	94.8	160.5	255.3	
	Total	5,088	10,219	505.1	1,046.5	1,551.6	14.92
1,000	Incineration	8,943	17,957	898.0	1,825.0	2,723.0	
	Ash lagoon	345	693	34.7	62.4	97.1	
	Landfill	1,496	3,004	150.2	321.7	471.9	
	Total	10,784	21,654	1,082.9	2,209.1	3,292.0	12.66

[a] All costs adjusted to reflect constant 1976. Heat recovery value assumed at $0.00/ton.
[b] Based on 260 days/year, 5 days/week, 8 hours/day.
[c] Includes site work, mechanical equipment, air pollution control equipment, scales, roads, structures, fencing, materials, installation, contractor's overhead and profit, and clay liners. Does not include land, engineering and legal fees, special foundation, cooling water, contingencies, incoming pick-up and haul, etc.
[d] Amortized at 8% interest, 20-year term, level debt service.
[e] Includes salaries and overhead, fuel, utilities, equipment maintenance and replacement, etc.

Source: Ref. II-23, III-42, 46

Table 3-7. ESTIMATED COSTS FOR SHREDDING AND LANDFILLING

			Estimated Costs[a]				
Input tons/day[b]	Process	Expenditure[c] 1,000	Amortized[d] capital cost $1,000	Annual amoritized capital $1,000	Annual[b] O&M $1,000	Total annual cost $1,000	Total cost/ input ton
100	Shedding	2,017	4,077	204.0	207.0	411.0	
	Landfill	1,077	2,162	108.1	180.6	288.7	
	Total	3,094	6,239	312.1	387.6	699.7	26.91
200	Shedding	2,361	4,740	237.0	204.0	441.0	
	Landfill	1,146	2,300	115.0	191.5	306.5	
	Total	3,507	7,040	352.0	395.5	747.5	14.38
400	Shedding	3,320	6,663	333.0	399.0	732.0	
	Landfill	2,007	4,031	201.6	283.9	485.5	
	Total	5,327	10,694	534.6	682.9	1,217.5	11.71
1000	Shedding	8,000	16,061	803.0	1,100.0	1,903.0	
	Landfill	4,244	8,524	426.2	525.4	951.6	
	Total	12,244	24,585	1,229.2	1,625.4	2,854.6	10.98

[a] All costs adjusted to represent 1976 dollars. Recovery from sale of compost not included.

[b] Based on 260 days/year, 5 days/week, 8 hours/day.

[c] Includes site work, mechanical equipment, scales, roads, fences, structures, clay liners, materials, installation, contractor's overhead and profit, etc. Does not include special foundations, engineering and legal fees, contingencies, rolling stock, etc.

[d] Amortized at 8% interest, level debt service, 20-year term (buildings and structures), 15-year term (shredders), 10-year term (spreading equipment). All costs, however, represent a 20-year cost.

[e] Includes salaries and overhead, fuel, utilities, equipment maintenance and replacement, etc.

Source: Ref. II-23, III-45,46.

Table 3-8. ESTIMATED COSTS FOR BALING AND COMPACTING PROCESS

				Estimated costs[a]			
Input tons/day[b]	Process	Expenditure[c] $1,000	Amortized[d] capital cost $1,000	Annual amortized capital $1,000	Annual O & M[e] $1,000	Total annual cost $1,000	Total cost/ input ton
100	Baling and compacting	950	1,384	69.2	93.0	162.2	
	Landfill	1,077	2,162	108.1	180.6	288.7	
	Total	2,027	3,446	177.3	273.6	450.9	14.45
200	Baling and compacting	1,901	2,767	138.4	186.0	324.4	
	Landfill	1,146	2,300	115.0	191.5	306.5	
	Total	3,047	5,067	253.4	377.5	630.9	10.11
400	Baling and compacting	3,802	5,534	276.7	371.9	648.6	
	Landfill	2,007	4,031	201.6	283.9	485.5	
	Total	5,809	9,565	478.3	655.8	1,134.1	9.09
1,000	Baling and compacting	9,504	13,836	691.8	929.8	1,621.6	
	Landfill	4,244	8,524	426.2	525.4	951.6	
	Total	13,748	22,360	1,118.0	1,455.2	2,573.2	8.25

[a] All costs adjusted to reflect 1976 dollars.

[b] Based on 260 days/year, 5 days/week, 8 hours/day.

[c] Includes site work, mechanical equipment, air pollution control equipment, scales, roads, structures, fencing, clay liners, materials, installation, contractor's overhead and profit, etc. Does not include land, engineering and legal fees, special foundations, cooling waters, contingencies, incoming pick-up and haul, etc.

[d] Amortized at 8% interest, level debt service, 20-year term (landfill), 10-year term (balers and compactors). All costs, however, represent the 20-year cost.

[e] Includes salaries and overhead, fuel, utilities, equipment maintenance and replacement, etc.

Source: Ref. II-23, III-42,

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Industrial Wastes

The residuals from pretreatment of industrial wastes must be contained in a properly designed, adequately controlled and monitored, chemical landfill. Hazardous waste residuals should be isolated from nonhazardous waste residuals to ensure safe operation of the landfill. A chemical landfill is designed to provide indefinite storage of waste chemical residuals and to protect the quality of ground water in or near the area.

However, proper and acceptable techniques of industrial waste management practices consist of intermediate practices, and ultimate disposal practices for proper handling of any residual materials. Typical intermediate practices seek to achieve the following:

1) Recover valuable chemicals at their source in the most concentrated state.

2) Analyze, revise, and up-date existing and projected chemical processes to achieve reduction of polluting materials at the source.

3) Close-loop once through cooling water usage by installation of on-site cooling towers, thereby reducing the hydraulic load to the sewer.

4) Reduce the amount of ad lib washes of process tanks and equipment (e.g. solvent wash, water wash, detergent wash, acid or alkali wash), and suitably contain, pretreat, and remove potential pollutants from the wash waters.

5) Adequately contain and dike all spills to insure their removal of pretreatment prior to sewer discharge.

6) Establish and regulate programs of preventative maintenance and housekeeping throughout the plant to reduce spills, leaks, equipment malfunctions, etc.

Table 3-9 illustrates typical process techniques suitable to handle specific pollution problems at the intermediate level of effort.

The typical costs associated with an intermediate industrial wastewater step are highly variable and generally site-specific as are the residuals that must be ultimately disposed of in chemical waste landfills.

Siting of the chemical landfill is critical (Ref. III-49). Criteria for site selection, although similar to those for general landfills, are more stringent:

Table 3-9. TYPICAL TECHNIQUES SUITABLE TO TREAT VARIOUS POLLUTANT CONTAMINANTS

Processes	pH	Acids	Alkalies	Settleable solids	Suspended solids	Heavy metals	Hexvalent chromium	Cyanide	Organic material	Oils	Phenol	Color bodies	Taste and odor	Herbicides and pesticides	Total dissolved solids	Thermal pollution	Nutrients	Phosphate	Nitrogen
Neutralization (pH adjustment)	X	X	X																
Chemical oxidation or reduction							X	X			X	X	X						
Sedimentation				X	X					X									
Clarification				X	X	X	X		X	X								X	
Filtration				X	X	X													
Flotation					X					X									
Ion exchange						X	X				X				X			X	X
Lagooning				X					X	X	X	X	X			X		X	X
Emulsion breaking										X									
Adsorption									X		X	X	X	X					
Biological treatment									X		X	X	X					X	X
Direct incineration								X	X	X	X								
Sludge dewatering				X	X	X			X	X	X	X	X						
Cooling towers																X			X
Desalinization techniques															X			X	X

A variety of unit processes are applicable for treatment of different contaminants. Various combinations of these processes may be incorporated into any waste treatment system. For instance, an organic waste containing solids above 65 to 70 mg/l would require clarification ahead of carbon adsorption.

Source: Ref. III-56.

Chemical waste landfills ideally should be located in areas of low population density, low alternative land use value, and low ground water contamination potential.

Sites should be located away from flood plains, natural depressions, and excessive slopes.

Wherever possible, sites should be located in areas of high clay content because of the low permeability and beneficial adsorptive properties of such soils.

Major sources of waste generation should be nearby. Wastes transported to the site should not require transfer during shipment.

Sites should be located an adequate distance from wells that serve as water supplies for human or animal consumption.

Detailed site studies and waste characterization studies are necessary to estimate the long-term stability and leachability of the waste sludges in the specific site selected.

Design and operation of the chemical landfill are extremely important. The site should be fenced to prevent public access. Where leachate may cause ground water contamination the use of liners, encapsulation, detoxification and/or solidification and fixation should be practiced (Ref. III-48). All liners, cover materials, and encapsulating materials must be tested or have known chemical resistance to the substances they will contain or otherwise come in contact with. Ideally, such materials should have an effective life greater than the toxic life of the wastes they contain. These precautions are needed to ensure that the chemical landfill is truly sealed and that it will not contaminate ground or surface waters by leaching or runoff.

Recent technological advances in liner fabrication provide a selection of materials for sealing a chemical landfill. These include asphalt, clay, concrete, rubber and a variety of plastics such as Hypalon or PVC. The choice of liner depends on economics and on ability to ensure an adequate seal given the chemical mix of the landfill. Table 3-10 summarizes typical costs for several types of liners (Ref. III-38). Figure 3-3 illustrates a properly designed chemical landfill.

Monitoring and Recordkeeping for the Chemical Landfill

Studies must be made to determine site monitoring requirements. Hydrogeological monitoring will be required to detect routine and accidental releases of liquid effluents. A system of observation wells should be installed in aquifers around the site and concentrated in paths of potential water and waste movement downstream from the site. A monthly

Table 3-10. COST FOR VARIOUS LANDFILL LINER MATERIALS

Liner material	Installed cost[c,d,e] ($/yd^2)
Polyethylene (10 - 20[a] mils[b])	1.13 - 1.81
Polyvinyl chloride (10 - 30[a] mils)	1.47 - 2.72
Butyl rubber (31.3 - 62.5[a] mils)	4.09 - 5.04
Hypalon (20 - 45[a] mils)	3.63 - 3.86
Ethylene propylene diene monomer (31.3 - 62.5[a] mils)	3.06 - 4.31
Chlorinated polyethylene (20 - 30[a] mils)	3.06 - 4.08
Paving asphalt with sealer coat (2 inches)	1.51 - 2.14
Paving asphalt with sealer coal (4 inches)	2.96 - 4.09
Hot sprayed asphalt (1 gal/yd^2)	1.89 - 2.52 (includes earth cover)
Asphalt sprayed on polypropylene fabric (100 mils)	1.59 - 2.36
Soil-bentonite (9.1 lbs/yd^2)	0.91
Soil-bentonite (18.1 lbs/yd^2)	1.47
Soil-cement with sealer coal (6 inches)	1.57

[a] Material costs are the same for this range of thickness.

[b] One mil = 0.001 inches.

[c] Costs are updated to 1976, and do not include construction of subgrade nor the cost of earth cover except where indicated. These can range \$0.58/yd^2/ft of depth.

[d] Materials and labor costs are included.

[e] Land costs are not included.

Source: Ref. III-38.

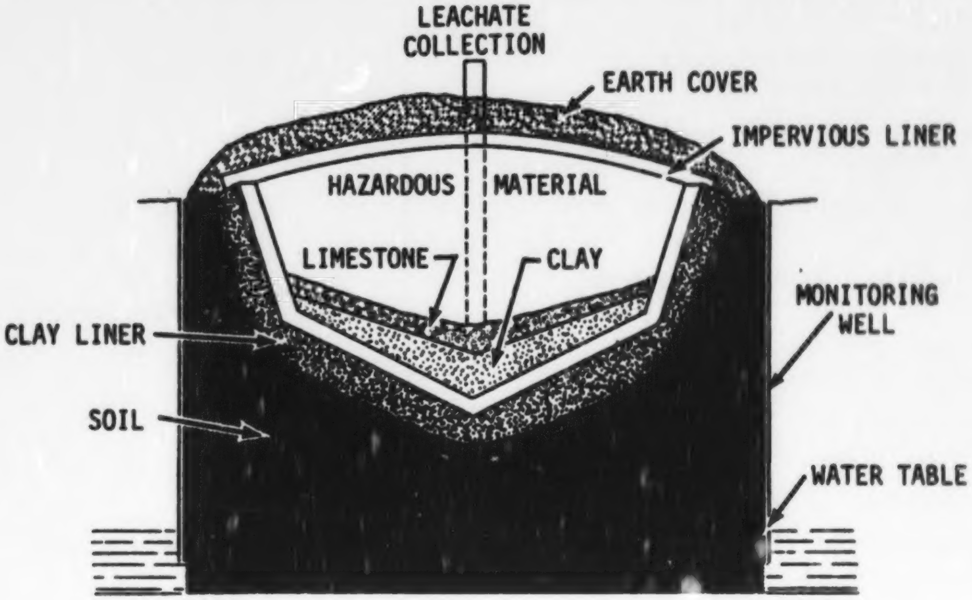
LEACHATE COLLECTION
EARTH COVER
IMPERVIOUS LINER
HAZARDOUS MATERIAL
LIMESTONE
CLAY
MONITORING WELL
CLAY LINER
SOIL
WATER TABLE

Figure 3-3. Pictorial representation of properly designed chemical landfill.

Source: Ref. III-48.

sampling frequency is suggested. Downstream monitoring stations and a bimonthly sampling frequency are suggested for surface streams in the vicinity of the chemical landfill site (See Appendix A).

The locations of various hazardous wastes within the landfill should be recorded to permit future recovery if economics permit. These results will facilitate the analysis of causes if undesirable reactions or other problems develop.

The capital and O&M costs associated with a chemical landfill are not well documented. Assuming that the chemical residuals are handled similarly and that loading factors are comparable to those for operation of a sanitary landfill, costs can be generated that reflect the order-of-magnitude costs for a chemical landfill operation. These costs are summarized in Table 3-11; they include the cost of a 45-mil, highly chemical-resistant, Hypalon liner. Land costs and transport costs are not included.

Since 1965 a plant at Union Carbide's Institute, West Virginia, has operated a state-licensed chemical landfill. Some 200 types of organic residuals from the plant have been placed in this landfill. Leachate from the landfill is contained and treated in the plant's 5.0 mgd activated sludge system or is burned as a source of heat for steam generation. Typically the landfill handles 10 tons (9.1 metric tons) per day of chemical waste sludges; the landfill is also sized to handle 28 tons (25 metric tons) of wastewater treatment plant sludges per day.

The Union Carbide landfill has a 2-foot (.6 meter) thick rolled-clay liner to keep leachate from entering adjacent ground waters. A 20-year life (based on 4,000 tons (3,632 metric tons) per year of chemical residuals disposal) has been projected for the landfill. An internal drainage system permits all-weather operation and collects the leachate for treatment. The basic operating procedures for hazardous waste disposal consist of strict segregation of in-plant wastes; deactivation before landfilling, where practical; continuous blending of wastes and soil, and daily earth cover. Union Carbide indicates that not all chemical wastes are degraded in the landfill. Some liquid flows out of the landfill as an "oil" layer into a contaminated water basin, where it is skimmed for residue fuel. Other waste leaves as dissolved chemicals in the leachate and goes to wastewater treatment.

Table 3-12 summarizes estimated costs for the expected 20-year life of the landfill.

The ultimate long-term utility of a given chemical landfill depends upon the assurance that leaching of chemical residuals does not occur. Several companies have developed ways to reduce the leachate potential of typical residuals by a chemical fixation process. Some companies

Table 3-11. ESTIMATED ORDER-OF-MAGNITUDE COSTS TO OPERATE A 100 TON/DAY CHEMICAL LANDFILL SITE

Tons/day	Tons/year[a]	Capital expenditure[b,c]	Total amortized capital costs[d]	Annual amortized capital costs	Annual O&M[e]	Total annual cost	Unit cost per ton[f]
100	31,200	2,710,108	5,436,476	271,823	454,195	726,018	23.27

[a] Based on 312 days/year, 6 days/week, 8 hours/day.

[b] All costs adjusted to represent 1976 dollars (i.e., 1976 = 100).

[c] Based on an in-situ compacted density of 800 lb/yd^3, 12 feet operating depth, and site efficiency of 85% (6582 tons/acre). Includes site work, scales, roads, fences, structures, materials, installation, surface, surveys, subsurface investigations, operating equipment, contractor's overhead, a 45 mil Hypalon lining, monitoring wells, and profit, etc. Does not include engineering and legal fees, contingencies, resource recovery, land costs, collection and haul to the landfill, etc.

[d] Amortized at 8% interest, 20 year term, level debt service.

[e] Includes salaries and overhead, fuels, utilities, equipment maintenance and replacement, analytical services, etc. Does not include collection and haul to the landfill, etc.

[f] No credit given for ultimate sale of completed chemical landfill site after 20 years.

Source: Ref. III-49.

Table 3-12. TOTAL COST FOR CHEMICAL LANDFILL OPERATION AT UNION CARBIDE'S INSTITUTE, WEST VIRGINIA PLANT

Tons/day[a]	Tons/year	Capital expenditure[b,c]	Total amortized capital costs[d]	Annual amortized capital costs	Annual O&M	Total annual cost	Unit cost per ton
13	4,000	314,928	631,745	31,587	181,682	213,269	53.31

[a] 312 days/year basis.

[b] All costs adjusted to represent 1976 dollars (i.e., 1976 = 100).

[c] Costs include all site work, and materials, leachate control and monitoring system, two foot rolled clay liner, oil skimmer device, etc. Does not include land costs and study or design costs.

[d] Amortized at 8% interest, 20 year term, level debt service.

Source: Ref. III-47.

offer a chemical fixative capable of locking a chemical residual into a solidified matrix. Following are typical materials that these companies claim to have rendered mostly insoluble or nonleachable:

- Heavy-metal wastes
- Neutralized pickling liquors
- American Petroleum Institute (API) oil-water separator sludges
- Polymer processing wastes
- Municipal sludges
- Petrochemical residues
- Flue gas desulfurization sludges.

One company claims that its fixative is nontoxic, noncombustible, and resistant to leaching even in the presence of highly acidic materials. It is also reported to reduce odors. The chemically-fixed materials could be placed in a chemical landfill similar to that of Union Carbide. Since the process represents a relatively new technology, cost data are limited. Typical costs range from 2 to 10 cents per gallon ($5.28 to $26.42/m^3), but this cost is highly contingent upon the type of wastes involved (Ref. III-48).

If a cost of 10 cents per gallon ($26.42/m^3), is assumed, and if half of the annual chemical wastes generated at Union Carbide are assumed to be suitable for this treatment (Table 3-12), an annual cost of $47,960 would be entailed in adding this process to the chemical landfill operation.

It is certain that chemical fixatives should and can reduce leachate of chemical residuals, but the permanence of the resulting structure and the absolute environmental adequacy of these techniques have not been fully demonstrated. When used with a well-designed and monitored chemical landfill operation, however, chemical fixatives should strengthen the protection of ground waters and streams (Ref. III-49).

Feedlot Wastes, Mining Wastes

Feedlot wastes and mining wastes are not normally landfilled.

Dredge Spoil

A sanitary landfill is not normally used to dispose of dredge spoil because of the typically large volumes. For small-scale dredging operation, or those involving highly polluted spoils containing heavy metals, disposal in a landfill may be considered with precautions to prevent leachate from reaching water courses.

3.6 OCEAN DISPOSAL

The Environmental Protection Agency controls the disposal of all wastes except dredge spoil, in the marine environment by a system of permits for discharge, transportation, and dumping. The U.S. Army Corps of Engineers controls dredging, subject to EPA review. The Marine Protection, Research and Sanctuaries Act, 1972 (40 CFR 220-227) promulgates strict criteria for the dumping of any waste to the oceans. These sections also promulgate interim guidelines until such time as applicants can bring their wastes within acceptable limits. At present there are 119 approved interim disposal sites.

In general the Federal guidelines set the limiting permissible concentration of pollutants as follows:

> (a) That concentration of a waste material or chemical constituent in the receiving water which, after reasonable allowance for initial mixing in the mixing zone, will not exceed 0.01 of a concentration shown to be toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures; or
>
> (b) 0.01 of a concentration of a waste material or chemical constituent otherwise shown to be detrimental to the marine environment.

These guidelines, all but eliminate any type of disposal in the marine environment except dredge spoil.

3.7 TRENCH SEWAGE SLUDGE DISPOSAL

Trenching is a modified landfill technique developed by the U.S. Department of Agriculture (U.S.D.A.) at Beltsville (Ref. III-50). Trenches 2 to 4 feet (.6 to 1.2 meters) deep and 2 feet wide are dug and filled with digested and raw-lined dewatered sludge and covered by earth. The soil cover prevents odor escape and contamination of surface water and permits digestion of sludges in the field. Because the interior of the trenched sluge mass is anaerobic, the rate of nitrate formation is slow and restricted to the aerobic perimeter. Stabilization and dewatering can take up to 5 years during which the land is out of agricultural use for this period.

Trenching has not been extensively employed for sludge disposal. As such, the information provided here should be viewed as substantially less than "state of the art" in usefulness. Additional guidance is available from Maryland Environmental Service (MES). The information presented below originates from a MES study (Ref. III-51).

3.7.1 Site Criteria

Site Size

An application rate of 1600 wet tons (1,453 metric tons) of filter cake per acre (320 dry tons/acre (717 metric tons/ha)) is recommended. Sites should therefore be chosen on the basis of maximum accommodation in order to minimize the frequency of site change.

Geology

The basic geology of the site should provide an adequate buffer from ground water. This would be particularly critical if the field capacity of the soil was exceeded and vertical movement of water occurred. Therefore, the ground water level should be 3 to 5 feet (0.9 to 1.5 meters), below the bottom of the excavated trench (Ref. IV-1).

Drainage and Topography

Sites should be relatively flat with no more than 7 percent slope in order to insure equipment stability.

Present and Final Land Use

The application of raw sludge was, in the MES studies, limited to lands on which edible crops would not be grown for a period of 5 or more years.

3.7.2 Operating Procedures

Field Trenching

Trenches are constructed with a standard trenching machine with a trencher wheel capable of indexing the full width of the machine from crawler to crawler and a spoil conveyor which can discharge to either side of the machine. Trenches are laid out to follow the contour of the ground. The initial trench is constructed before any sludge is received and the next consecutive parallel trench is escavated in a manner which allows its excavation spoil to be directly conveyed as cover for the sludge placed in the previously excavated trench. A trenching machine with an 18-inch (45.7 cm), wheel with offset teeth to excavate a 24-inch (61.0 cm), wide trench is considered adequate.

Environmental Considerations

The following practices are recommended for any trenching site: drainage diversions, sedimentation ponds, clear water ponds, monitoring wells and surface monitoring stations. If surface water in the ponds indicates contamination, the water can be spray irrigated on the previously completed areas.

Upon completetion of sludge application and cover, the surface should be limed, fertilized, and seeded with an annual rye grass mix until the trench sludge has stabilized. When stabilization has occurred, the area should be leveled and seeded with a permanent grass mixture.

Detailed costs for the trenching method are not available. Preliminary estimates gave costs of $30.00 per wet ton ($33.00/metric ton) ($150/dry ton ($165/metric ton)) which included hauling, disposal, and land acquisition.

3.8 DIVERSION AND DRAINAGE OF SURFACE RUNOFF

One significant problem common to some management practices (MP's) discussed in this chapter is the control of surface runoff in the vicinity of treatment or disposal sites. The surface runoff at the site of land spreading for sludge disposal or the facilities for feedlot wastes disposal will tend to pick up and disperse pollutants in a manner which is environmentally unsatisfactory. Pollution of the nearby surface waters is a common and direct consequence. As to landfill sites used for residual wastes disposal, especially during the active stage of operation when the landfill site is not yet sealed off, any uncontrolled runoff will tend to flood the site and increase the generation of leachate.

The remedy to these problems usually requires a surface diversion and drainage system properly designed for the specific site. Essentially, this represents a basic engineering refinement for some of the management practices although, unfortunately, it has been ignored in many instances at the present time.

3.8.1 General Design of the Systems

In general, surface runoff may be diverted and drained by engineering works such as dikes and/or channels, which will be discussed separately in the following sections.

3.8.1.1 Dikes - Dikes are usually designed to protect lowlands against periodic innundation by storm floods or high water (Ref. III-52). They are most comonly constructed with earth although the use of other materials such as concrete is also possible. The general design of earth dikes involves the following considerations:

1. Location of Dike

The location of dikes is determined by the flood-protection requirements, e.g. the location of the facility to be protection, topography, and foundation conditions.

2. Cross-Section of Dike

The most common cross section is usually in trapezoidal shape, with slopes determined by the requirements of soil stability as well as construction economics. Since the fill material must frequently be derived from shallow borrow pits located near the site of the dike, the stability requirements may dictate the degree of compaction for the fill material and may thus affect the construction cost. If soil stability is not a critical constraint, the land area available for dike construction will determine the steepness of the slopes and consequently the construction cost.

3. Height of Dike

The height of the dike will be determined by the rate of surface runoff which is to be dealt with. In turn, the rate of surface runoff depends on the characteristics of the topography and hydrology of the specific site.

4. Length of Dike

The length of dikes is determined by the area to be protected from the surface runoff and the topography of its surroundings.

3.8.1.2 Channels or Ditches - Open channels or ditches, which are less objectionable in rural rather than urban areas, are widely used for the drainage of surface water, at a considerable cost saving over that of buried pipes (Ref. III-53).

Open channels or ditches are a common alternative to dikes for the diversion of surface runoff. The choice between dikes and channels mainly depends on the topography of the site and the economics of the construction. The use of a combination of dikes and channels for certain sites may well be a possibility. The major difference between dikes and channels lies in the mode of construction, dikes are made of filling material while channels are generally constructed by cutting into the ground in accordance with the local topography.

The major considerations for the design of drainage channels are as follows:

1. Design flows

The design capacity of drainage channels is influenced by (1) precipitation, (2) size of the contributing area, (3) topography, (4) soil characteristics, (5) presence of vegetation, and (6) degree of protection warranted.

Typical design has been to remove about one percent of the mean annual rainfall in twenty-four hours, which is usually in the range of one-quarter to one-half of the 1-yr, 24-hr rainfall (Ref. III-53).

2. Channel Lining

Channel lining refers to the lining of earth channels with materials harder, more impermeable (impervious to water), and more stable than the natural base soil. These linings are intended to achieve one of the following two important objectives.

(a) To increase the channel's resistance to scour, or, in other words, to increase the maximum permissible velocity;

(b) To prevent water seepage from the channel or, at least, to reduce it.

According to these two objectives, linings may be classified as follows (Ref. III-54).

Type of lining	Increase in scour resistance	Reduction of seepage losses
Vegetative lining	yes	no
Lining with a layer of impervious soil	slightly	yes
Masonry lining	yes	no
Masonry lining with connecting mortar	yes	slightly
Lining with a bituminous layer	slightly	yes
Concrete lining	yes	yes

3. Maintenance

Timely maintenance is necessary for the continued satisfactory operation of drainage channels. The principal causes for the failure of open drainage channels are, in the order of decreasing seriousness, sedimentation in the channel, excessive growth of vegetation, and channel and bank erosion (Ref. III-55).

3.8.3 Costs

As described in the preceding paragraphs, the capital cost of dikes and channels has to be a function of the volume of earthwork involved, the construction method used, the type of channel lining utilized, etc. In general, these considerations are highly site-specific, depending on local topography, soil characteristics, etc.

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4.0 TECHNICAL/SCIENTIFIC ASPECTS

This section of the Handbook is devoted to the technical and scientific regimes that figure most strongly in management of residual wastes, some examples of which are described in Section 2. It focuses on the movement and fate of residuals that are placed on or beneath the earth's surface, citing some of the possible effects of climate, topography, vegetation, soil chemistry, and, perhaps most importantly, ground water hydraulics. A summary of key concepts is given in Table 4-1.

It is obviously impracticable to deal with the full range of technical complexities that could be or are involved in site evaluation and residuals management. The aim, rather, is to acquaint planners, engineers, and others, with the nature of problems that may arise in using management practices described in Section 3, how they may be diagnosed, and how they may be dealt with. Examples applying technical and scientific aspects in terms of BMP's are developed in hypothetical, but realistic, case study scenarios in Section 6. In virtually all cases, the planners will require professional assistance. A further aim of this section of the handbook, therefore, is to acquaint the planner with some of the basic technical terms and their application, so that in discussions with specialists, he may understand their findings and the logic applied in reaching them.

To reduce the number of possible combinations of technical factors to a manageable level, various condensations have been made. For example, because irrigation, infiltration-percolation, disposal, and some ponds impose high liquid-loading rates on the soil, subsoil, and aquifer, they can be considered together in discussing the effects of infiltration and aquifer permeability on disposal. Although design and construction are not specifically addressed, numerous suggestions and recommendations for effective design of disposal facilities are inherent in the technical discussions.

4.1 EFFECTS OF CLIMATE

Almost all ground water is part of the earth's water circulatory system known as the hydrologic cycle (Figure 4-1). In this process, water is continually evaporated from oceans and seas and precipitated on land surfaces. A portion of this precipitation runs off overland and returns to the oceans via rivers and streams; another portion infiltrates

Table 4-1. SUMMARY OF KEY CONCEPTS PERTAINING TO RESIDUALS DISPOSAL ON LAND

1. One hundred percent containment of residuals disposed of on or in the ground is, for all practical purposes, impossible.

2. In water-table (unconfined) aquifers, the flow pattern of ground water is in general accord with the topography, i.e., from ridges toward valleys (except in arid zones).

3. Residuals disposed of on or in the ground will contaminate ground water, which in turn will contaminate surface water (except in some arid regions). The degree of such contamination will depend upon the disposal method and management practice.

4. Swamps and marshes are usually natural ground water discharge areas.

5. Contaminated ground water moves through the aquifers as a discrete body, and is not subject to rapid dilution.

6. The location of a disposal area downgradient from, or to the side of, existing wells will not necessarily prevent contaminants from moving to the wells when they are pumping.

7. The presence of trace amounts of heavy metals in ground water does not necessarily indicate contamination.

8. A high infiltration rate in the soil profile at a proposed disposal site where high liquid loading rates will be involved does not, of itself, ensure that the site is hydraulically suitable.

9. Monitor wells must be properly located, and screened at the proper depths, or they will fail in their purpose.

10. The reclamation of a contaminated aquifer is usually impossible, for practical purposes, where the area involved is large (over a few acres), or the contaminant persistent (as in the case of hydrocarbons). If the source of contamination is removed, natural recovery may take place over years or decades.

11. Soil is a chemically and biologically dynamic medium: Soil minerals and organisms can react with residues in many ways to change their physical and chemical characteristics.

12. Soil texture and clay mineral composition are important in selecting residuals disposal sites because potential for attenuation varies over a wide range with differing soils.

13. The attenuation capacity of a soil for metals is finite and governed by the cation exhange capacity (CEC). If the CEC is exceeded, migration of cations with percolate would occur. CEC is further discussed in Appendix C.

14. Elements unaffected by cation exchange may contaminate ground water if they are added in excess of crop needs and natural mechanisms leading to loss as gases (nitrate and sulfate).

15. Cations which are adsorbed may be released by addition of other cations, changes in pH, or changes in oxidation-reduction potential. Thus adsorption is not necessarily a permanent removal of cations from soil solution.

16. Phosphate, unlike other negatively charged ions, is adsorbed or fixed in most soils.

17. The chemical species of nitrogen or sulfur which are applied to soil may be changed as percolation occurs and these elements enter biochemical cycles.

18. Plant uptake of nutrients is not limited to those in soil solution. Therefore, a portion of adsorbed heavy metals, for example, are available to plants.

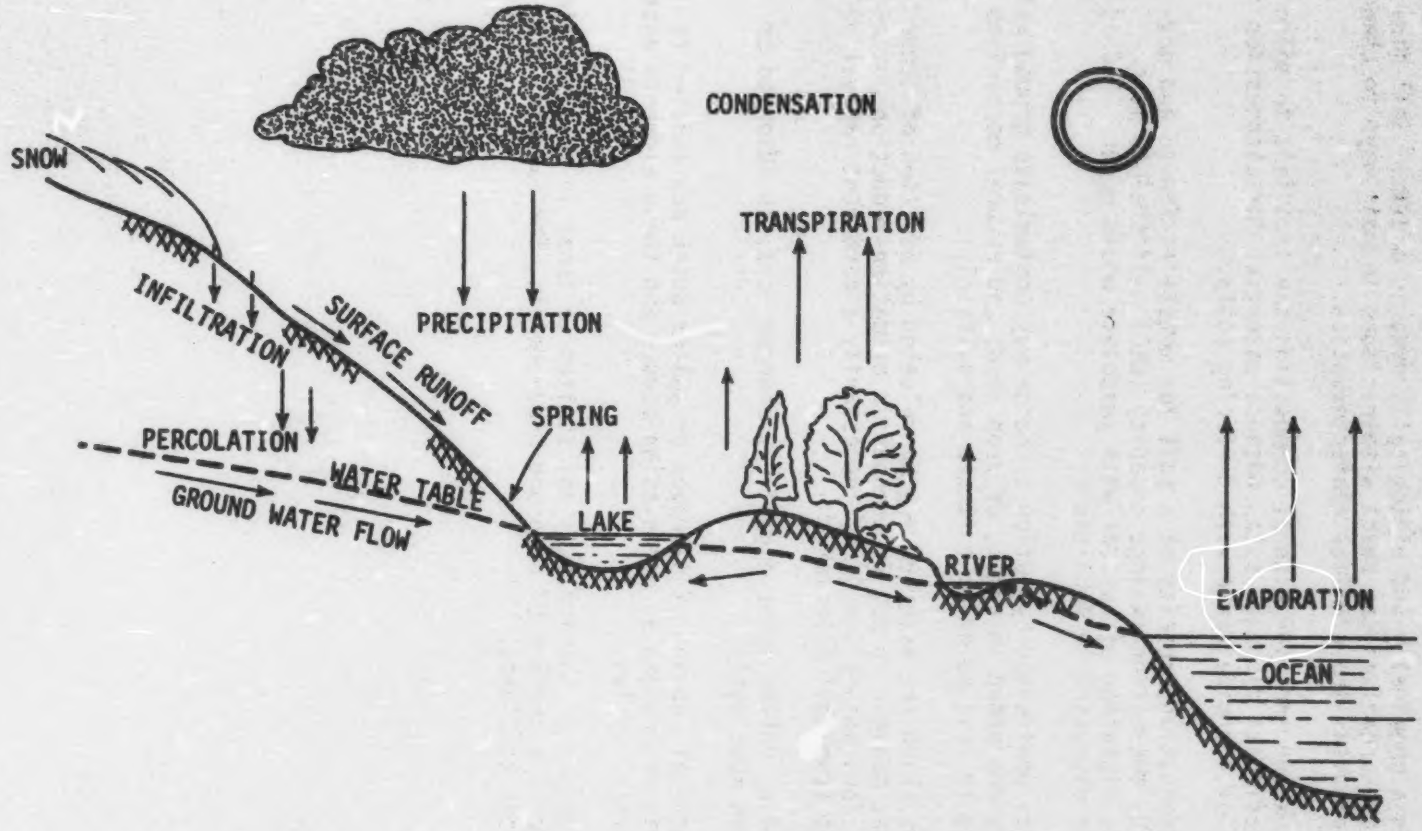

CONDENSATION
SNOW
PRECIPITATION
TRANSPIRATION
INFILTRATION
SURFACE RUNOFF
PERCOLATION
SPRING
WATER TABLE
GROUND WATER FLOW
LAKE
RIVER
EVAPORATION
OCEAN

Figure 4-1. The hydrologic cycle.

Source: Ref. IV-1.

through the unsaturated zone under the action of gravity and replenishes ground water reservoirs or aquifers. Natural discharge of ground water occurs as flow into surface water bodies, such as rivers, lakes, and oceans, and as springs at the land surface. Water may return directly to the atmosphere by evaporation or by transpiration from vegetation (referred to collectively as evapotranspiration). Another climatic effect on ground water is that of air temperature, which controls the temperature of ground water near the earth's surface.

Patterns of precipitation, evapotranspiration, and prevailing air throughout the nation are fairly well known; long-term basic data for most regions are available from the National Climatic Center, from the Agricultural Extension Service, Agricultural Experiment Stations, and from local weather stations and airports. The effects of precipitation and evapotranspiration as well as pumping on ground water are discussed in greater detail in the following sections.

4.1.1 Precipitation

Records of rainfall and snowfall are required to estimate the rate of ground water recharge in the general area of a proposed disposal site. Many planning agencies routinely collect these records. If such records are not available, estimates may be made by comparisons with nearby areas having similar characteristics and for which data are available. Because rainfall may vary greatly from month to month and year to year, long-term averages should be used. Experience has shown that good records covering 35 years are correct within 2 percent. For data covering 20, 15, 10, and 5 years of record, the probable deviations from mean rainfall will be 3.25, 4.75, 8.25, and 15 percent respectively (Ref IV-2). In ground water investigations rain gauges are often installed on a temporary basis to provide data for correlation of rainfall and ground water fluctuations. Installation of rain gauges at potential waste disposal sites to determine overall rainfall patterns is not warranted, however, since long-term records are required.

The other major form of precipitation is snowfall. Although the water content of snow varies greatly, 10 inches of freshly fallen snow is generally considered equivalent to 1 inch of rainfall. Melting snow can provide considerable ground water recharge when it takes place gradually, since infiltration continues over a relatively long period of time.

Overland runoff depends on precipitation and is affected by watershed characteristics, including topography, geology, and soil conditions. Runoff is an extremely important factor in site selection and design of waste-disposal facilities. Disposal sites must be protected from flooding, which may interrupt disposal activities, damage facilities, and cause pollution of surface water bodies. Provisions must be made for abnormal weather patterns and emergency situations. These may take the form of extra land or storage facilities or large drainage and ditch systems.

4.1.2 Evapotranspiration

Evapotranspiration is the evaporation of moisture from water, soil, snow, ice, and other surfaces, plus transpiration. In water-budget studies or calculations of the balance between water gains and losses in a particular basin, evapotranspiration is a key factor. The degree of ground water recharge (R) depends entirely on precipitation (P), direct runoff (R), and the amount of precipitation consumed by evapotranspiration (ET) and returned to the atmosphere. The equation $R=P-ET-RO$ expresses this concept in the simplest terms, indicating that precipitation not consumed by evapotranspiration and not discharged to rivers or seas by direct runoff recharges the ground water reservoir. Information on ground water recharge rates is useful in calculating infiltration rates and movement of pollutants below waste-disposal sites. Unfortunately, few studies have been made to determine recharge rates, which vary enormously because of the wide variation of climatic conditions in the nation. In the humid eastern seaboard region, precipitation is high and evapotranspiration losses are low; thus, recharge rates are relatively high (20 inches or over). In contrast, in arid western sections of the country, precipitation is low and evapotranspiration rates are high, resulting in zero or very low rates of recharge. In those "water deficit" areas, replenishment of ground water reservoirs takes place during rare periods of intense precipitation or through infiltration from surface water bodies. In arctic areas, precipitation is generally low (much of it in the form of snow) and evapotranspiration is low. Infiltration is generally low because of frozen ground (permafrost) and ice on the land surface.

Direct evaporation of ground water occurs where the water table is close to the surface, for example, in swampy or heavily irrigated areas. Where the water table lies more than 3 feet below the land surface, such water losses are minimal.

Liquid industrial wastes are frequently disposed of in evaporation ponds. At present, many of these lose much of the liquid through the bottom of the pond, to ground water. Where such losses are controlled by any method, however, accurate information on evaporation and precipitation is essential for both planning and design, since the surface area must be large enough to evaporate (on a yearly basis) a volume of water equal to the input. The ponds must also have adequate volume for storage during periods when evaporation is reduced or non-existent. Other considerations are the very gradual reduction in evaporation rate as the liquor in the ponds becomes more concentrated, and the loss of storage volume due to precipitation of solids from solution or the direct introduction on insoluble material.

4.1.3 Ground Water Levels and Fluctuations

Evaluation of a potential waste-disposal site requires knowledge of the elevation and shape of the water table and its fluctuation patterns. The depth to water and the thickness of the unsaturated zone must be known in order to assess the effect of leachate from waste disposal at the surface on ground water and to assess the potential for renovation of waste fluids. The position of the water table, or top of the saturated zone, varies with topographic and geologic conditions, ground water recharge, irrigation practices, and neighboring discharge zones including rivers, lakes, and pumping wells.

The water table fluctuates in direct response to the amount of recharge water. In the humid eastern zone of the nation, precipitation and ground water recharge are highest during the early spring and lowest in late summer and fall. Ranges of fluctuation are related to geologic structure; in some poorly drained, closed basins the water table fluctuates as much as 15 feet. In irrigated arid zones, water-table elevations generally decline during the growing season when evapotranspiration losses are high. Because precipitation that falls during the growing period is not sufficient to offset such water losses, recharge in such areas takes place almost exclusively from ditch loss and excess irrigation water.

Ground water levels also fluctuate as a result of changes in river stages and nearby pumpage. For example, adjacent to rivers and lakes, water levels in shallow wells will rise during periods of high runoff and floods, then decline when streamflow diminishes. The magnitude of such fluctuations is greatest in wells nearest the water bodies. Pumpage from water-table aquifers or even artesian aquifers in the vicinity of a disposal site may cause lowering of water levels, which will rise again when pumping operations are halted. Site evaluation should include an inventory of nearby wells to obtain details on location, well construction, depth, water-bearing formation, pumpage, and water quality. If good long-term records of water levels are needed, one or more observation wells at or near the site should be equipped with an automatic water-level recorder. Analysis of the fluctuation recorded by these instruments will yield information on seasonal variations of water levels and effects of pumpage or irrigation.

4.1.4 Ground Water Quality

Climatic conditions strongly affect the quality of ground water. Assuming similar geologic environments, shallow ground water in a humid or a high-recharge section of the country will be less mineralized than that in an arid or low-recharge region as a result of dilution by precipitation.

Contrary to common belief, rain and snow are not "pure" but contain small concentrations of chemical constituents including dust particles and gases that are collected from the atmosphere. The concentrations of chemicals are low, however. On Long Island, New York, precipitation contains about 10 ppm of dissolved solids, mainly sulfate, chloride, and sodium (Ref. IV-3). Rain may also contain corrosive industrial air pollutants, and highly acid rain has been encountered in much of the Northeast (Ref. IV-4). From the planner's point of view, however, the impact of the quality of precipitation on waste disposal and ground water may be considered minute.

In semi-arid or arid zones, shallow ground water is often mineralized because it moves slowly in such environments and is longer in contact with the geologic formations. Further, in most environments, the dissolved-solids content of ground water increases progressively with depth. Irrigation and evapotranspiration often contribute to mineralization of ground water. Irrigation and successive recycling of water also increases the concentration of minerals in water and at the root zone of plants. Evapotranspiration causes an upward movement of shallow ground water and deposition of mineral salts at or below the land surface.

The importance of obtaining background water-quality data in the vicinity of a proposed disposal site cannot be overemphasized. Without such data it may be very difficult, or even impossible, to determine the presence and extent of any except gross contamination. As has been pointed out, the natural quality of ground water varies widely, sometimes over relatively short distances. Also, pre-existing sources of contamination, if not recognized by the planner, could lead to the condemnation of a perfectly well-managed residuals disposal program. These water quality investigations should be carried out regardless of the types of prevention or mitigation procedures that are under consideration.

As part of the water-quality survey, representative wells near the proposed site should be sampled; the samples should be analyzed for a broad spectrum of constituents, since many natural waters contain minor elements in detectable amounts. These trace elements are widely but mistakenly considered to be absolute proof of contamination, primarily because until recent years the quantitative determination of these elements was so difficult, expensive, and error-prone that very few such determinations were made. As a consequence, many persons believe that, for example, zinc has not been commonly reported as a constituent of natural water, its presence must be an indication of contamination. This has been refuted with respect to zinc and cadmium, and by inference should apply to other trace constituents (Ref. IV-5). Thus if background levels of chemical constituents are established prior to the institution of residuals disposal, it will be easier to determine later whether the trace elements are valid indicators of contamination (see Appendix A). Table 4-2 gives a list of recommended determinations, which should be reviewed by someone knowledgeable of local conditions. For example, selenium might be added in parts of the Southwest.

Prior use of the proposed disposal area should be considered by the planner and in some cases may dictate the inclusion of analyses for insecticides or other exotic organics (see Appendix C). The type of disposal that is being planned will also affect the analytical plan.

Where major constituents can be used as tracers, they are preferable. A comparison of 100 milligrams to 10 milligrams per liter of chloride can be used with much more confidence than a comparison of 10 micrograms to 1 microgram per liter of cadmium, although the ratios are the same. For despite the advances in instrumentation, the analysis of minor elements remains difficult.

Samples should be taken only by a person experienced in the problems that may be involved, preferably using bottles provided by the laboratory that will perform the analyses (see Appendix B). It is essential that the laboratory be informed in advance of the determinations that will be required. The selection of wells to be sampled should be done by a hydrogeologist or ground water hydrologist.

4.2 TOPOGRAPHY

Also to be considered in selection of disposal sites are type and slope of the land surface. Relationships between topography and ground water are discussed briefly in this section.

4.2.1 Elevation

Below the hills and mountains, the water table is generally found at a greater depth than in adjacent flat-lying regions. Topography of the area surrounding a proposed site should be studied and the drainage basin divides should be determined prior to calculating surface water runoff. Poorly drained valleys or basins might not be suitable for waste disposal because of the danger of flooding or large fluctuations of ground water levels. Upland areas, in contrast, could provide a visual barrier to unsightly waste-disposal practices and could serve as a buffer zone. Swampy areas, where the water table is close to the surface, are not suitable for waste disposal because of potential for pollution of surface waters.

Table 4-2. RECOMMENDED DETERMINATIONS FOR BACKGROUND GROUND WATER QUALITY

Primary Constituents[a]

Sodium
Potassium
Calcium
Magnesium
Carbonate
Bicarbonate
Sulfate
Chloride

Secondary Constituents[b]

Iron
Arsenic
Manganese
Chromium (total & hexavalent)
Cadmium
Zinc
Lead
Nitrate
Nitrite
Fluoride
Phosphate
Copper
Mercury
Ammonium

Other

pH and temperature (to be taken at the sampling point)
Specific conductance.

Any other constituents that may be expected to be present in the disposed residual.

[a] Indicates background constituents usually more prevalent in ground water.

[b] Although possibly more harmful to water quality, these constituents are usually secondary in background occurrence.

Relief of the land surface is a further important consideration. Heavily incised terrain would require extensive filling; hilly or uneven terrain might require levelling to allow for effective waste disposal and optimum operation and maintenance. On crop-land irrigation sites, topography must allow the use of farm equipment.

4.2.2 Slope

Most waste-disposal operations require level or near-level terrain. Liquid waste-disposal methods, however, which employ overland flow require slopes of 2 to 4 percent (Ref. IV-6). For ridge-and-furrow irrigation the slope of a site can be changed by terracing. Spray irrigation has been practiced in areas with slopes up to 30 percent (Ref. IV-7). Flooding requires a slope of 0.2 to 0.3 percent. Low-contour check ridges or terraces are required to allow uniform distribution of liquid wastes.

The slope of a site has no immediate bearing on the position of the water table except that in areas of steep slope the thickness of the unsaturated zone may vary greatly. Slope, however, determines the velocity of surface water runoff. Recommendations for minimum distances between site and surface water course have been made to prevent potential surface water pollution from waste-disposal (Ref. IV-8).

As shown in Table 4-3, land slopes greater than 9 percent are not suitable for land application of processed organic wastes. The higher the slope, the greater the required minimum distance between site and river course.

4.3 INFILTRATION

Infiltration is the movement of water through the soil surface into the soil, whereas percolation is the movement of water through soil and subsoil into the ground water body. The two phenomena are closely related, and there can be no rigorous separation. Accordingly, they are treated together here, with a cautionary note to the planner that reference is to the behavior of water in the soil profile. Where disposal methods involving high liquid loading rates are being considered, the permeability (both vertical and horizontal) of the underlying rock must be taken into account. This is because the application rate will considerably exceed the natural rate of liquid application (precipitation), and if a moderately permeable soil overlies a poorly permeable rock, the latter may be unable to transmit the applied liquid to the water table and thus away from the surface at a rate sufficient to prevent ponding and surface runoff.

Table 4-3. RELATION OF SLOPE TO DISTANCE FROM WATER COURSE

Maximum sustained slope, %	Minimum distance to water course, ft.	
	Processed organic waste application. May to Nov. inclusive	Processed organic waste application, Dec. to Apr. inclusive
0 to 3	200	600
3 to 6	400	600
6 to 9	600	No processed organic waste to be applied.
Greater than 9	No processed organic waste to be applied except under special conditions.	No processed organic waste to be applied

Source: Ref. IV-8.

4.3.1 Factors Affecting Infiltration Rates

The rate of infiltration, usually expressed in inches per hour or cm/sec., depends upon many factors: intensity and duration of precipitation; surface slope; conditions of soil surface; temperature; type and stand of vegetation; and porosity, grain size, aggregation, and moisture content of the soil. The essential point is that there must be adequate pathways through the soil surface to conduct the water. These pathways are usually intergranular pores, but cracks in the soil may also be effective and in clayey soils may be the principal avenue of infiltration (Ref. IV-9).

A bare soil surface is often subject to a rapid reduction of its rate of intake of the beginning of a rainstorm, when a thin compact layer forms on the surface. This surface-sealing effect is greatly reduced or eliminated if the surface is covered with close-growing vegetation or with a mulch, such as straw, sawdust, or leaves. These materials absorb the energy of the raindrops, control the sorting effect of surface flow, and help to maintain an open soil structure. The introduction of organic material (with the obvious exceptions of petroleum products and many industrial organics) will improve and maintain soil structure; hence the application of municipal sludges should be beneficial to infiltration.

Disposal of residual wastes introduces other possibilities for alteration of the soil structer, possibly unfavorably. Application of an agricultural waste eventually has altered the soil so greatly that infiltration and percolation were converted entirely to sheet runoff (Ref. IV-10,11). The use of heavy equipment in the disposal area will compact the soil and thus decrease infiltration. This latter is desirable in landfill operations but could cause problems with sludge disposal on land.

Constraints imposed by soil below the root zone are found primarily in the C horizon as defined below:

> A mineral horizon or layer, excluding bedrock, that is either like or unlike the material from which the solum is presumed to have formed, relatively little affected by pedogenic processes, and lacking properties diagnostic of A or B but including material modified by: (1) weathering outside the zone of major biological activity; (2) reversible cementation, development of brittleness, development of high bulb density, and other properties characteristic of fragipans; (3) gleying; (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by such accumulations as calcium or magnesium carbonate or more soluble salts; or (6) cementation by alkali-soluble siliceous material or by iron and silica.

Various types of cementation may retard or prevent water penetration, which in turn can result in mounding of water into the zone of aerobic biological activity or to the surface. The effect of such cemented zones, or pans, usually can be eliminated by proper land preparation and management.

The term "gleying" denotes an intense reduction of iron to the ferrous state during soil formation. This could affect the behavior of heavy metals in the percolate.

Freezing of soils also reduces infiltration rates, the degree of reduction being roughly a function of the degree of saturation. A frozen saturated soil permits virtually no infiltration, and even at maximum retention capacity the infiltration rate is much lowered.

When considering the application of residuals to land in cases where infiltration rates are a factor, consideration must be given to chemical composition of the residual. A high sodium content relative to calcium and magnesium contents is undesirable, since ion exchange processes may cause the soil to become dispersed and puddled. This will adversely affect plant growth as well as infiltration rates. The measure of the degree of sodium hazard is the sodium-absorption-ration (SAR):

$$\mathrm{SAR} = \mathrm{Na}^{+}/\sqrt{(\mathrm{Ca}^{++} + \mathrm{Mg}^{++})/2}$$

where the concentration of the ions is expressed in milliequivalents per liter. The SAR is then considered in conjunction with the electrical conductivity of the water (a function of total dissolved solids), to determine the classification of the water. This evaluation is well known for irrigation waters, but it could also be applied to any liquid residual.

4.3.2 Field Estimation of Infiltration Rates

Infiltration rates may be estimated from field experiments. The simplest procedure involves two concentric metal rings, pressed into the ground. Water is introduced into both, maintaining a level about a quater of an inch above the soil surface. Measurements are taken of the water required to maintain the level in the inner ring only, since the water in the outer ring serves only to provide a buffer zone that inhibits lateral movement of water infiltrating from the inner ring. Infiltration rates thus obtained are about twice those found with sprinkler-type infiltrometers (Ref. IV-9), and hence the use of ring infiltrometers should be restricted to cases where flood or furrow disposal of effluent is planned.

Sprinkler-type infiltrometers simulate rainfall, and can be adjusted to provide various intensities. Plots used for such studies range from about 2 to nearly 500 sq ft (Ref. IV-12). Nozzles are precalibrated for discharge rates, and runoff is measured, infiltration being the difference between the two. The simulation of actual rainfall is imperfect, since (among other things) the drops do not reach terminal velocity and drop-size distribution differs. Data provided by the sprinkler-type infiltrometers should be satisfactory, however, for evaluation of plots for spray-irrigation disposal. Field experiments and interpretation of data should be carried out by an experienced hydrologist.

The foregoing discussion is not intended to imply to the planner that field experiements are required in all site evaluations. In some cases, as with excavated ponds, preliminary evaluations by such methods would be meaningless. Where infiltration rates are important (primarily in disposal by spray irrigation and by infiltration-percolation) data sources given in the following section will often provide adequate information; otherwise field reconnaissance by an agricultural hydrologist or soils scientist may suffice.

A cautionary note: the "perc" test that is commonly used to determine the suitability of soils for septic tank installations is absolutely unsuited to evaluation of residuals disposal sites. Lateral flow generally constitutes a considerable portion of the measured percolation, and since the maximum testing depth is about 4 feet, it would be possible that an impermeable layer at perhaps 6 feet would not be detected.

Good guides to the infiltration characteristics of the soils at proposed land-disposal sites are the county soil surveys issued by the Soil Conversation Service, U.S. Department of Agriculture. The newer series incorporate photo-maps at scales as large as 1:15,840 (four inches to one mile). The surveys include descriptions of the various soil series and phases, information often useful for other purposes in the site analyses (e.g., determining erosion hazards, seasonal high water tables, and acceptable vegetation). In the absence of the newer series, other maps are often available, together with the soil descriptions. In many areas, however, no soil maps of any type are available. Complete information about the available data may be obtained from the nearest office of the Soil Conservation Service, School of Agriculture, or County Extension Service Agent.

4.3.3 Constraints Imposed by Geology

Even if the soils at a proposed disposal site provide suitable infiltration and percolation rates for land application of residuals at a high liquid-loading rate, the nature of the underlying rocks may preclude use of the site or require special facilities. As an example, the Pennsylvania Department of Environmental Resources Spray Irrigation Manual (Ref. IV-13) comments on shales as follows:

> Most shale terrains are poor site choices because high secondary permeabilities, resulting from fracturing. Those that have open fractures will short circuit wastewater directly to the ground water. Some shales are deeply weathered and may provide adequate renovation of the irrigated wastewater. Others may be so tight as to reject infiltrating water, form a perched water table, and eventually discharge this water to the surface or cause surface-water ponding.

Some problems of poor percolation to the aquifer may be met by installing tile drains, if ground water recharge is not an important consideration. This is not commonly done, however. Irrigation on slopes, with subsequent return of the effluent as springs discharging to surface water bodies, may also be acceptable providing that adequate renovation is achieved through the land.

Geology at the site and in the vicinity will also dictate the most effective use of wells to recover the renovated water or (if necessary) to create enough drawdown to maintain the water table at a sufficient depth. In some cases, the latter approach may be more effective than the use of drains.

Although fissured or cavernous rock formations generally are to be avoided, they do not necessarily disqualify a site, provided that the soil cover is sufficiently thick, and that the system is designed with full knowledge of subsurface conditions. The effluent disposal area for the University Park - State College, Pennsylvania, system is underlain by solution-channeled limestone and dolomite, but a very thorough site investigation prior to its establishment made it possible to avoid any problems (Ref. IV-14).

A summary of the realtive importance of site variables is given in Table 4-4.

4.4 GROUND WATER HYDRAULICS

As in the earlier presentations, this discussion of ground water hydraulics is intended to provide for the planner an understanding of basic concepts. It will not equip him to perform the functions of a trained hydrogeologist, but it should help him to appreciate the many technical considerations that may affect a potential disposal operation.

By way of introduction, two points are emphasized. First, the disposal of residuals on land, in the absence of impermeable barriers, may be

Table 4-4. RELATIVE IMPORTANCE OF SITE VARIABLES WITH RESPECT TO DISPOSAL METHODS

	Landfill	Land spreading	Spray irrigation	Infiltration percolation	Overland flow	Ponds and lagoons	Burial
Precipitation	XX	X	XX	X	X	XX	X
Temperature	0	X	XX	X	XX	X	0
Ground slope	X	X	XX	X	XX	0	0
Infiltration	XX	X	XX	XX	X	XX	X
Soil chemistry	0	XX	XX	XX	XX	0	0
Depth to water table	XX	X	XX	XX	X	X	XX
Permeability of aquifer	XX	X	X	XX	X	X	0
Existing or potential vegetation	0	X	XX	X	XX	0	0
Existing or potential well fields	XX	XX	X	XX	X	XX	XX
Evaporation	0	0	0	0	0	XX	0

Explanation:
XX Primary importance
X Secondary importance
0 Negligible importance

Also see Appendix C

expected (except in arid regions) to contaminate ground water, which in turn will contaminate surface water. Until it is definitely proved otherwise, this assumption should be made in all site investigations. Second, unlike disposal into surface waters, the dilution of contaminants within an aquifer is generally insignificant and cannot be counted on to mitigate adverse effects. Although both of these points are discussed in detail in the following text, they are mentioned here for emphasis, since failure to appreciate them is widespread.

4.4.1 Basic Hydrogeological Systems

Practically all ground water originates as precipitation during the hydrologic cycle as briefly discussed earlier in connection with climate. Of the water reaching the land surface in the form of rain or melting ice or snow, a portion infiltrates into the ground water reservoirs and moves through these either a part of or all the way back to the ocean. The water that infiltrates into the ground occupies voids between rock particles. Permeable rock formations that serve as reservoirs for the storage and transmission of water are called aquifers. Several distinct aquifer types are recognized differing in rock type and nature of their intensities, as shown in Figure 4-2.

4.4.1.1 Aquifer Systems - Once precipitation infiltrates into the ground under the influence of gravity, it moves through the unsaturated zone to the zone of saturation, where it enters the ground water reservoir. Unconfined water is found in this zone of saturation whenever the upper surface (or water table) is at atmospheric pressure and is free to rise and fall with changes in volume of stored water. Water-table aquifers are of prime concern in site evaluation studies, since the hydrologic impact of waste disposal on land occurs primarily within the upper zone of the earth's surface. When a well is constructed in a water table aquifer, the water in the well stands at the same level as the water table immediately outside the well. This level fluctuates seasonally in response to variations in rates of natural recharge, as discussed earlier.

If deeper aquifers are present below a site, the water in such formations is likely to be confined to some degree. Confined or artesian water occurs in aquifers that are separated from the zone of aeration by rocks of markedly lower permeability. Confined water completely fills the aquifer. The water level in a well drilled in an artesian aquifer stands above the top of the aquifer and is dependent on the artesian pressure. When that pressure becomes high enough, the water in such a well may rise above the land surface, causing the well to flow. Water levels in artesian wells, referred to as potentiometric levels, fluctuate in response to such natural factors as tides, barometric changes, and variations in rate of recharge.

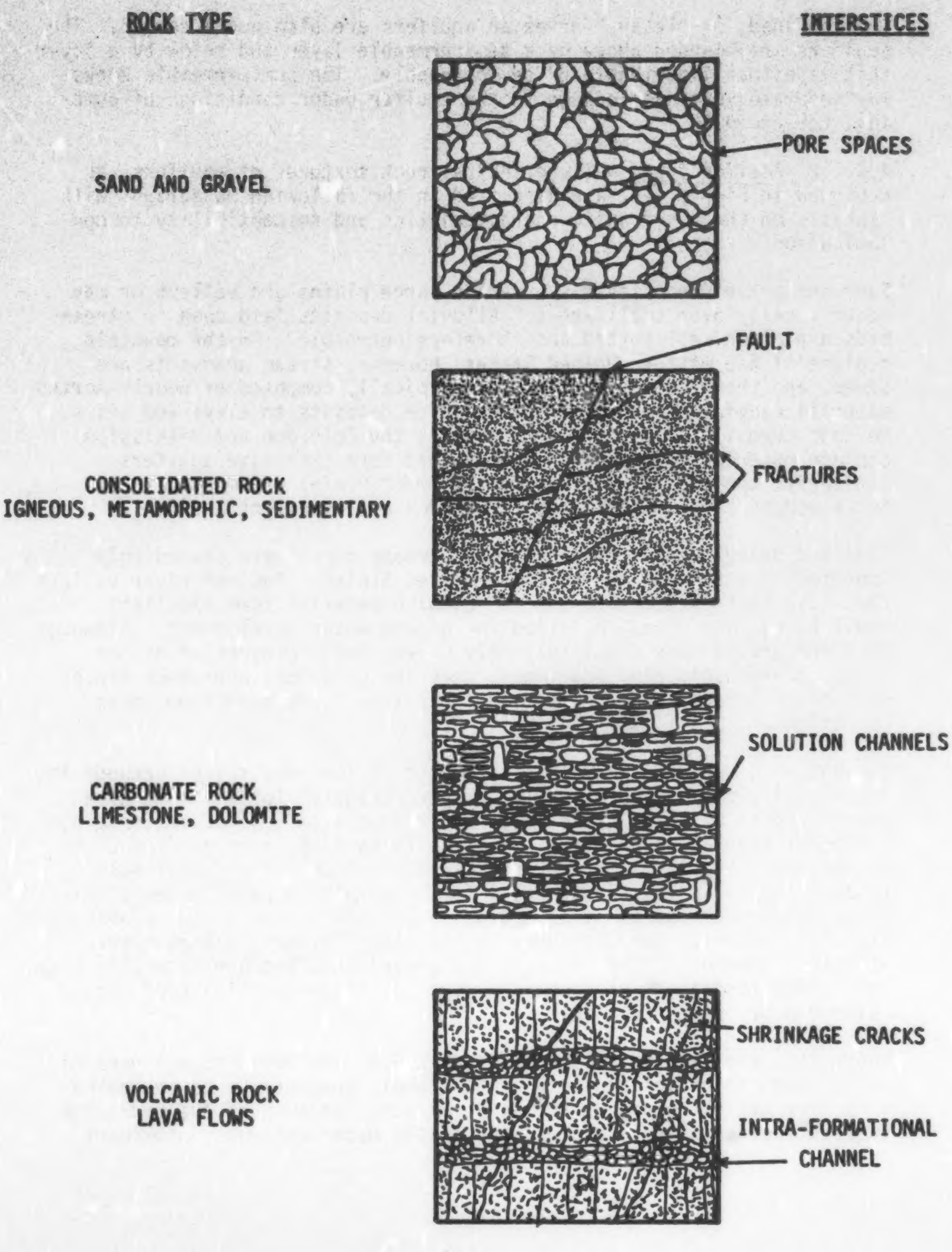

ROCK TYPE
INTERSTICES
SAND AND GRAVEL
PORE SPACES
FAULT
CONSOLIDATED ROCK
IGNEOUS, METAMORPHIC, SEDIMENTARY
FRACTURES
CARBONATE ROCK
LIMESTONE, DOLOMITE
SOLUTION CHANNELS
VOLCANIC ROCK
LAVA FLOWS
SHRINKAGE CRACKS
INTRA-FORMATIONAL
CHANNEL

Figure 4-2. Rock texture in major aquifer types.

Semiconfined, or "leaky," artesian aquifers are also quite common. The aquifers are bounded above by a semipermeable layer and below by a layer that is either impermeable or semipermeable. The semipermeable zones may generate vertical leakage to the aquifer under conditions of pumping, for example.

4.4.1.2 Aquifer Types - The principal rock textures of aquifers, as depicted in Figure 4-2, are discussed in the following paragraphs with emphasis on their hydraulic characteristics and susceptibility to contamination.

Sand and gravel deposits may underlie large plains and valleys or may occur locally over small areas. Alluvial deposits laid down in stream beds are often well sorted and therefore permeable. In the mountain regions of the western United States, however, stream gradients are steep, and the alluvial aquifers are typically composed of poorly sorted material ranging from boulders and coarse deposits to clays and silts. Deltaic deposits of large rivers such as the Colorado and Mississippi contain numerous coarse-grained beds that form extensive aquifers. Similarly, the coastal plains and the Great Plains are underlain by thick wedges of streamlaid deposits which are excellent aquifers.

Sand and gravel deposited by glacial streams constitute exceedingly important aquifers in the northern United States. Ancient river valleys that have been filled with glacial outwash material form excellent aquifers and are widely utilized for ground water development. Although sand and gravel beds constitute only a very small proportion of the total of unconsolidated sediments, they are of prime importance since most of the ground water pumped in the nation is derived from these formations.

The water in sand and gravel is contained in the pore spaces between the individual grains. The porosity, or percentage of total volume of a rock occupied by voids or interstices, ranges from 1 to 50 percent. In a typical sand and gravel aquifer porosity is high, ranging from 20 to 30 percent. The permeability, or ease with which a fluid will pass through it, indicates the capacity for transmitting water under a differential head. (Rocks of low porosity generally have a low permeability also, but high porosity does not necessarily imply a high permeability.) Permeabilities in sand and gravel aquifers are generally high and, under conditions of adequate recharge, large quantities of ground water can be pumped from them.

Where they are exposed to the land surface or lie below thin layers of soil, sand and gravel aquifers are extremely susceptible to contamination from wastes dumped on the land surface. Because of the hydraulic interconnection of pore spaces, the ground water and any contaminant that has reached it can move easily through the aquifer. Although rates of ground water movement in sand and gravel aquifers are relatively slow, varying from inches to a few feet per day, contaminants can spread over a considerable area before reaching the ultimate discharge point, which is commonly a body of surface water. Frequently, however, ground water flow patterns are modified by pumping from nearby wells, and the contaminated ground water converges upon the center of pumping. Confined sand and gravel beds are less susceptible to contamination, but pollutants can enter the aquifer either directly by infiltration on the outcrop of the aquifer or indirectly, as a result of a vertical leakage of contaminated water through the confining layer.

In addition to the unconsolidated deposits, the earth's crust is composed of consolidated rocks, including sandstone, conglomerates, and shales (the consolidated equivalents of sand, sand and gravel, and clay), schist, gneiss, quartzite, slate, granite, and basic igneous rocks. Carbonate rocks (limestone and dolomite) and volcanic rocks are discussed separately because of their unusual water bearing features. Individual consolidated rock formations range in thickness from a few feet to thousands of feet. Except for those of igneous origin, these rocks were originally deposited as sediments in a variety of geologic environments. Igneous rocks, representing magmatic activity in the earth's crust, later intruded into these rocks. Tectonic activity, including mountain building, has structurally deformed the rock sequence and is responsible for widespread fracturing of these consolidated rocks.

In sandstones and conglomerates, the individual particles usually have been cemented together, and porosity is reduced to such an extent that they yield very little water. Exceptions are sandstones that are only partially cemented. Most metamorphic and igneous rocks have little or no intergranular porosity, and their water-yielding characteristics are based entirely on the nature and interconnection of bedding planes, fractures, and joints within the rock. Ground water is contained in these and in the weathered zones. Studies have shown that fractures and permeability in consolidated rock are most common in the upper few hundred feet of the aquifer.

Fractured rock aquifers exposed at the land surface are highly susceptible to contamination. Waste fluids can enter the aquifer through fractures and can be rapidly dispersed over considerable distances by traveling along rock channels. Where the fractures are open, contaminated fluids can move easily without the benefit of adsorption, ion exchange, or filtration by fine-grained sedimentary material. Dispersion of contaminants that follow permeable fracture systems will tend to be highly irregular in depth and extent; the exact paths of contaminant movement are practically impossible to determine. In many parts of the country, sedimentary and crystalline rock aquifers are overlain by glacial till or clays. In such cases, the underlying aquifers are protected to some degree from contamination.

Carbonate rocks constitute 5 to 10 percent of all sedimentary rocks. Some of these rocks have also been subjected to tectonic stresses causing fractures. Moreover, since they are highly susceptible to solution by water, many formations contain large cavities and subterranean channels. Notable limestone terraces are found in central Tennessee, in the Shenandoah Valley of Virginia, and on the Florida Peninsula.

The carbonate rocks vary widely in permeability. Solution channels and cavities in limestone can be so large that the aquifers store vast amounts of water and are extremely productive. In Pennsylvania, for example, such water-filled conduits range from a few feet to over 70 feet in height and range in length from thousands of feet to 10 miles or more (Ref. IV-15). Permeability development is highly irregular, and channels may be separated by considerable amounts of solid rock.

Where limestone is exposed at the land surface, infiltration from rainfall and movement of ground water have created numerous passageways. Contaminants can pass through the solution channels unfiltered to enter the ground water reservoir. Dispersion of the contaminated ground water is extremely irregular because of variation in permeability. Ground water flow through channels may be so rapid that contaminated water moves over great distances in a very short time.

Basalt, a dark volcanic rock, is an important aquifer in the western part of the United States. Originating as lava flows, these basalt deposits have spread out over large areas in successive sheets of varying thickness. On the Columbia Lava Plateau in Oregon, Washington, and Idaho, individual lava flows are 20 to 500 feet thick, and the total thickness is some 10,000 feet.

The porosity of basalt aquifers is generally less than that of sands and gravels, but the permeability may be many times greater. Water moves through porous zones between successive lava beds, and through lava tubes, shrinkage cracks, and joints in a way similar to that in karstic limestone reservoirs (see Figure 4-2). Permeability in some basalt aquifers is so great that under natural conditions there is practically no slope to the water table or to the potentiometric surface in artesian systems. Where they are exposed or close to the land surface, these aquifers are extremely susceptible to contamination if fractures or shrinkage cracks provide direct access to the ground water reservoir. Rates of ground water movement through the permeable zones are relatively high, and dispersion of contaminants can be rapid if flow becomes turbulent.

4.4.2 Nature of Ground Water Flow

Except in special cases, ground water is constantly flowing from areas of recharge to areas of discharge. This flow is normally nonturbulent and is governed by Darcy's Law, which states that the quantity of water that will flow across a section of an aquifer during any given period is directly proportional to the coefficient of permeability of the aquifer material, the hydraulic gradient, and the cross-sectional area. Fuller discussions of Darcy's law and ground water flow in general are available to the planner in any standard text on the ground water or fluid flow in porous media (Ref. IV-16,17).

The coefficient of permeability (often referred to simply as "permeability") is a quantitative expression of the aquifer material's capacity for transmitting water. It should not be confused with porosity, which is the percentage of voids (pores or fractures) in a unit volume of the aquifer. There is no simple relationship between the two quantities. Although a number of units of permeability are in common use, in this report it is given as the rate of flow in gallons per day through a cross-sectional area of 1 foot, under a hydraulic gradient of 1 foot per foot (Ref. IV-18).

In solution of ground water equations, transmissivity is commonly used instead of permeability. Transmissivity is defined as the flow through a vertical strip 1 foot wide, extending through the full saturated thickness of the aquifer, under a hydraulic gradient of 1 foot per foot. Field problems are often solved on the basis of an aquifer width of 1 mile and a gradient of 1 foot per mile, which is the exact equivalent of the basic definition. A modified form of Darcy's law that is then used in ground water studies is:

$$Q = TIL$$

Where Q is the flow in gallons per day, T is the transmissivity, I is the hydraulic gradient, and L is the width of the cross section under consideration. The physical significance of the terms involved is shown in Figure 4-3.

The final physical characteristic fundamental to ground water studies is the coefficient of storage (S), a dimensionless term defined as the volume of water released or taken into storage by an aquifer per unit change of head per unit area.

The rate of ground water flow varies enormously, since the permeability of aquifer materials covers a range of 9 or 10 orders of magnitude. Thus under hydraulic gradients commonly encountered in nature, velocities range from tens of feet per day to 1 foot in tens of thousands of

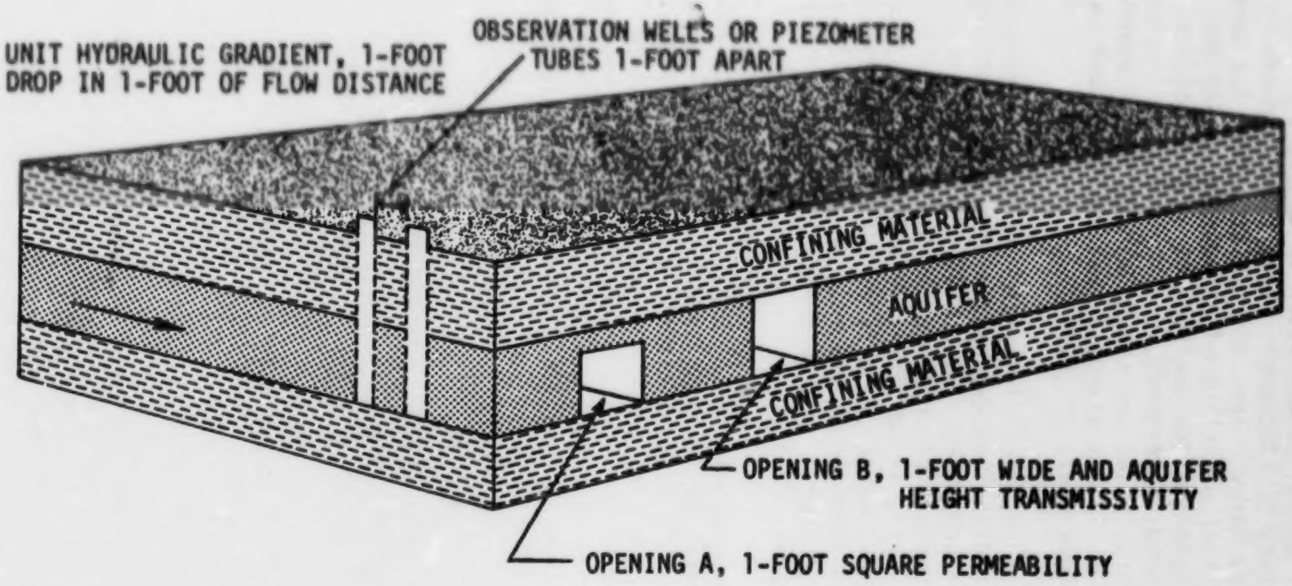

UNIT HYDRAULIC GRADIENT, 1-FOOT DROP IN 1-FOOT OF FLOW DISTANCE
OBSERVATION WELLS OR PIEZOMETER TUBES 1-FOOT APART
CONFINING MATERIAL
AQUIFER
CONFINING MATERIAL
OPENING B, 1-FOOT WIDE AND AQUIFER HEIGHT TRANSMISSIVITY
OPENING A, 1-FOOT SQUARE PERMEABILITY

Figure 4-3. Diagram for permeability, transmissivity, and hydraulic gradient.

Source: Ref. IV-19.

years. Flow rates in most aquifers, however, range from a few feet per day to a few feet per year.

4.4.2.1 Ground Water Flow Patterns - In water-table aquifers the flow pattern is in general accord with the topography, i.e., from ridges toward valleys, except in arid zones. Completely confined flow also generally follows this pattern but on a much broader scale, being little if any affected by minor topographic features. Cases of leaky artesian flow can be complicated, and exhibit unexpected flow patterns. In all cases, the true flow pattern may be established by preparing a ground water contour map, using the water level elevations in existing wells and observation wells or piezometers installed for this purpose. When these elevations are plotted on the base map, the water-level contours are plotted in exactly the same manner as topographic contours. Since each contour represents a line of equal energy head, it is referred to as an equipotential line. Ground water flow lines cross these equipotential lines at right angles (with some exceptions), the direction of flow being from higher to lower potential, or head. These two families of lines form a flow net, an example of which is given in Figure 4-4. Simple inspection of such a net provides information on relative transmissivities, as well as direction of flow. For example, the transmissivity in square "b" is less than in square "a," since a greater hydraulic gradient is required to move the same amount of water across it, the volume of flow between any two flow lines being a constant. Flow nets may also be constructed in vertical section, providing a three-dimensional display. These are sometimes essential to the proper construction of observation wells and to an understanding of the overall flow regime. Obtaining third-dimensional details, however, requires installation of many more observation wells at various depths. These usually are not needed to obtain information simply on direction of flow. The observations that delineate ground water flow patterns usually entail no great expense, but proper interpretation of the data requires experience and judgement.

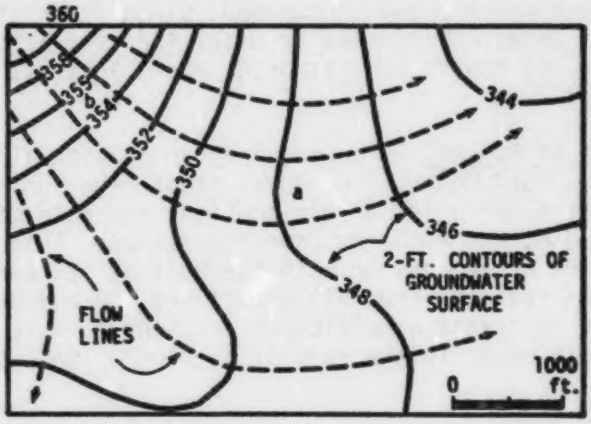


Figure 4-4. Contour map of a ground water surface showing flow lines.

Source: Ref. IV-1.

4.4.2.2 Flow Patterns of Contaminants - With respect to disposal of wastes, the planner must understand that contaminated ground water moves through the aquifer as a discrete body and is not subject to rapid dilution by the full volume of uncontaminated water within the aquifer. The body of contaminated water extending away from the disposal area is referred to as a plume. The shape of the plume and its rate of movement are determined by a complicated combination of factors, including ground water velocity, methanical dispersion at the microscopic level, macroscopic dispersion caused by inhomogeneities in the aquifer, differences in density and viscosity, and molecular diffusion. Collectively, these phenomena are referred to as hydrodynamic dispersion, which results in the contaminant occupying an ever-increasing cross section of the aquifer as it moves away from the source. The mathematical analysis of this phenomenon is extremely complex for even the simplest system (Ref. IV-17).

Figure 4-5 illustrates a typical flow path, in section, of a contaminant from the disposal area to the discharge area. No attempt has been made to show the effects of dispersion. In this case, these effects are somewhat offset by the compression of flow lines as they approach the discharge area.

Figure 4-6 is the plan view of an observed contaminant plume (Ref. IV-20). It involves a plume of plating-waste contamination on Long Island that probably has been studied longer and in more detail than the effects of any other similar incident. Contamination started in 1941; four studies of its extent and effects were carried out between 1949 and 1964, when the length of the plume was about 4300 feet. Movement is through the highly permeable sands and gravels of an upper glacial aquifer. The contamination limits were established from data provided by about 100 small-diameter test wells. This figure also illustrates a previously discussed factor affecting the flow pattern of contaminants: the mounding of ground water. The flow has been superimposed upon the natural flow pattern, and eventually has been swept away by it, but the plume of contamination has been broadened, since it originates from a base (the ground water mound) that is wider than the actual disposal area. (Ground water mounds are discussed and illustrated further in Section 4.4.2.5.)

4.4.2.3 Effects of Pumping - Pumping from an aquifer alters the natural flow pattern of ground water, the degree of alternation depending upon the hydraulic characteristics of the aquifer, the rate of pumping, the duration of pumping, and recharge characteristics. This alteration consists of a cone of depression with the well at the center, towards which water flows radially from all directions. Drawdown within the well is required to create a sufficient gradient to move water towards the well at a rate equal to the rate of pumping. The radius of the cone

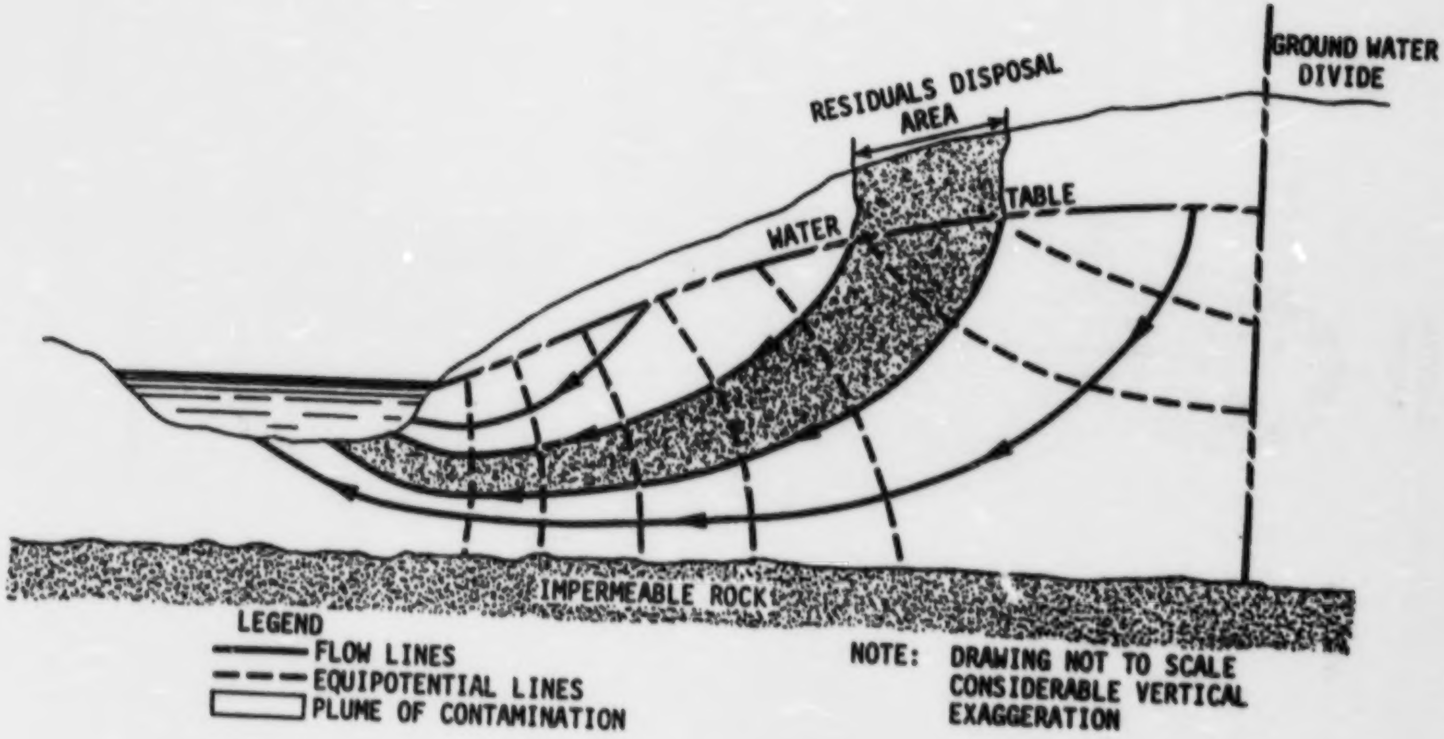

GROUND WATER DIVIDE
RESIDUALS DISPOSAL AREA
TABLE
WATER
IMPERMEABLE ROCK
LEGEND
FLOW LINES
EQUIPOTENTIAL LINES
PLUME OF CONTAMINATION
NOTE: DRAWING NOT TO SCALE CONSIDERABLE VERTICAL EXAGGERATION

Figure 4-5. Contaminant flow in a water-table aquifer

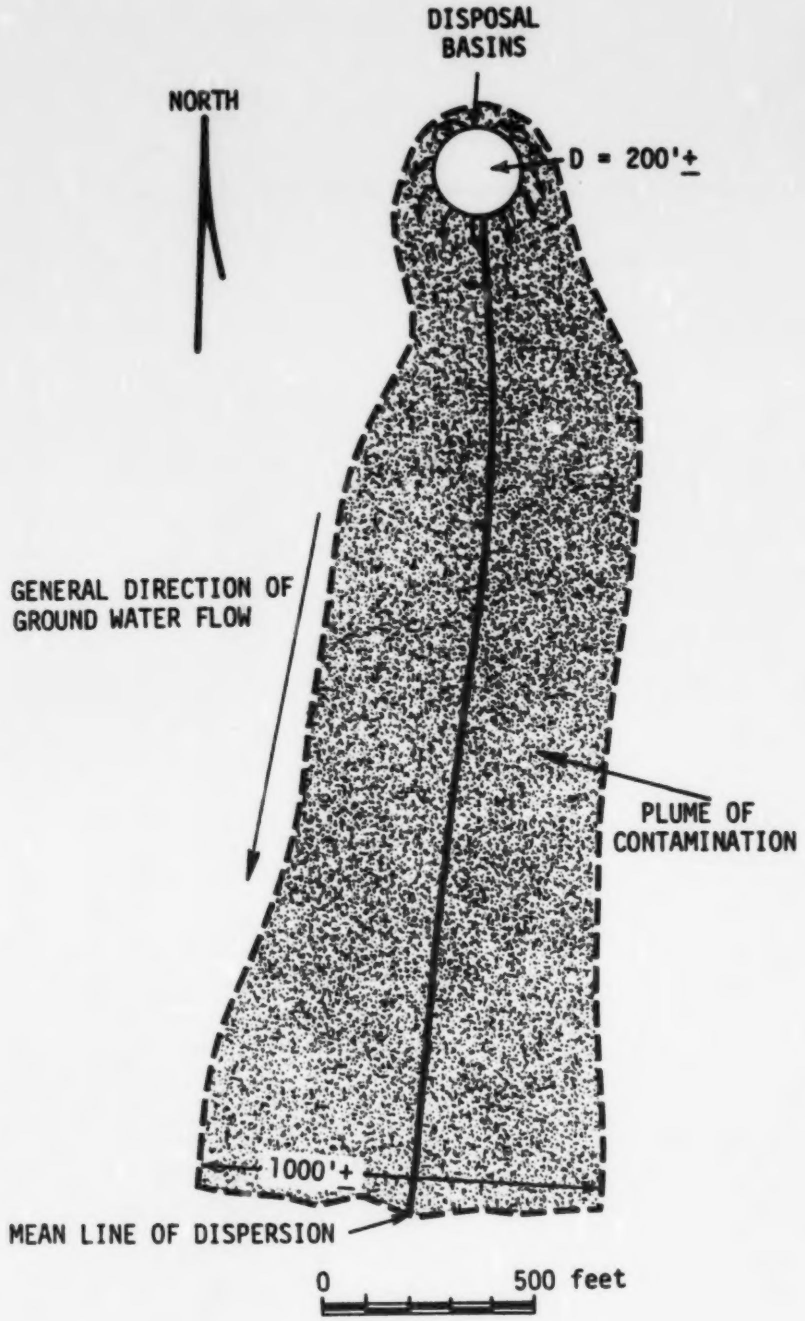

DISPOSAL
BASINS
NORTH
D = 200'±
GENERAL DIRECTION OF
GROUND WATER FLOW
PLUME OF
CONTAMINATION
1000'±
MEAN LINE OF DISPERSION
0
500 feet

Figure 4-6. Plume of contamination from an industrial waste disposal site.

is also called the radius of influence. The effect of transmissivity on this radius is shown in Figure 4-7. Since the drawdowns required to move water to the well are less in the more transmissive aquifer, but the volume of water pumped is the same, the radius of influence is greater. As a corollary, wells in highly transmissive aquifers will capture contaminants at greater distances than those in aquifers of low transmissivity.

The rate of spread of a cone of depression, and its volume after any given volume of water has been pumped, is much greater in a confined aquifer than in a water-table one. The cone of depression around major centers of pumping, especially in artesian aquifers, can extend over hundreds (or even thousands) of square miles. One effect of this cone of depression on wells pumping in the vicinity of a plume or source of contamination is shown in Figure 4-8, which illustrates that undesirable effects cannot always be eliminated by locating a well or well field either out of the line of the natural plume or upgradient from the source.

On the other hand, Figure 4-9 illustrates that even in a direct-line downgradient from the source only a portion of the water flowing to the well will consist of contaminated water. Again, these diagrams show the planner simple cases of perfect radial flow; the patterns would be distorted by inhomogeneities in the aquifer; by streams, lakes, or impermeable rock barriers within the radius of influence; or by other pumping wells nearby.

Pumping from aquifers in a multiple-aquifer system alters the head relationships among them, and can reverse the naturally occurring interaquifer transfer of water. Upward and downward leakage involving both artesian and water-table aquifers can occur as the natural heads are altered by pumping. Thus, even a confined aquifer is not necessarily protected from contamination. If the overlying water-table aquifer is contaminated, some of the contaminants may eventually reach the confined aquifer and hence the well.

4.4.2.4 Hydraulic Boundaries - The general ground water flow patterns can be much affected by the presence of hydraulic boundaries. This is particularly true when active wells are involved, and hence such boundaries must be considered when evaluating the potential effects of residuals disposal on adjacent wells or well fields.

Hydraulic boundaries are of two types: impermeable and recharging. An impermeable boundary is defined as a vertical plane across which no flow can occur, such as a granite ridge lying on one side of an alluvial aquifer.

A recharging hydraulic boundary, also called a line source, is defined as a vertical plane beyond which the pumping well can cause no drawdown. Such conditions are created by streams or lakes.

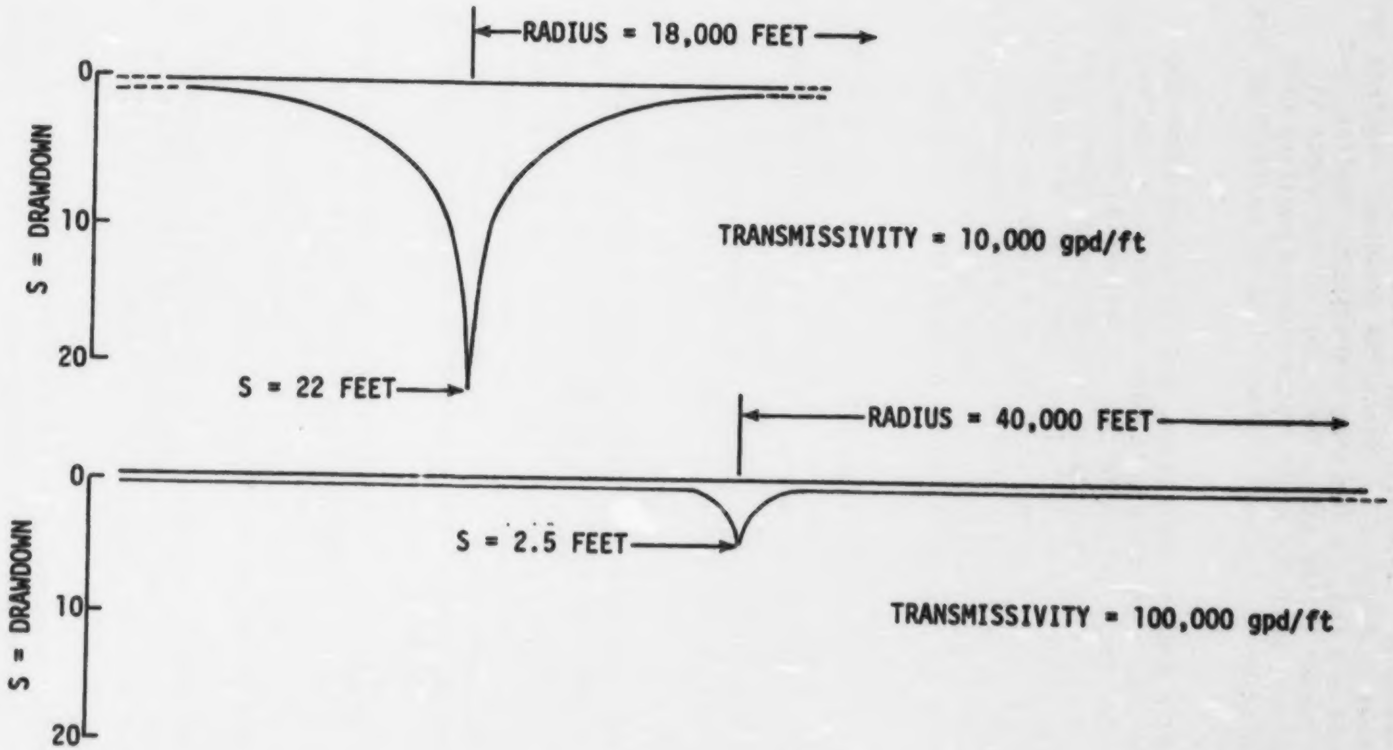

RADIUS = 18,000 FEET
0
10
20
S = DRAWDOWN
TRANSMISSIVITY = 10,000 gpd/ft
S = 22 FEET
RADIUS = 40,000 FEET
0
10
20
S = DRAWDOWN
S = 2.5 FEET
TRANSMISSIVITY = 100,000 gpd/ft

Figure 4-7. Effect of differing coefficients of transmissivity upon the shape, depth, and extent of cone of depression. Pumping rate and other factors being the same in both cases.

Source: Ref. IV-21.

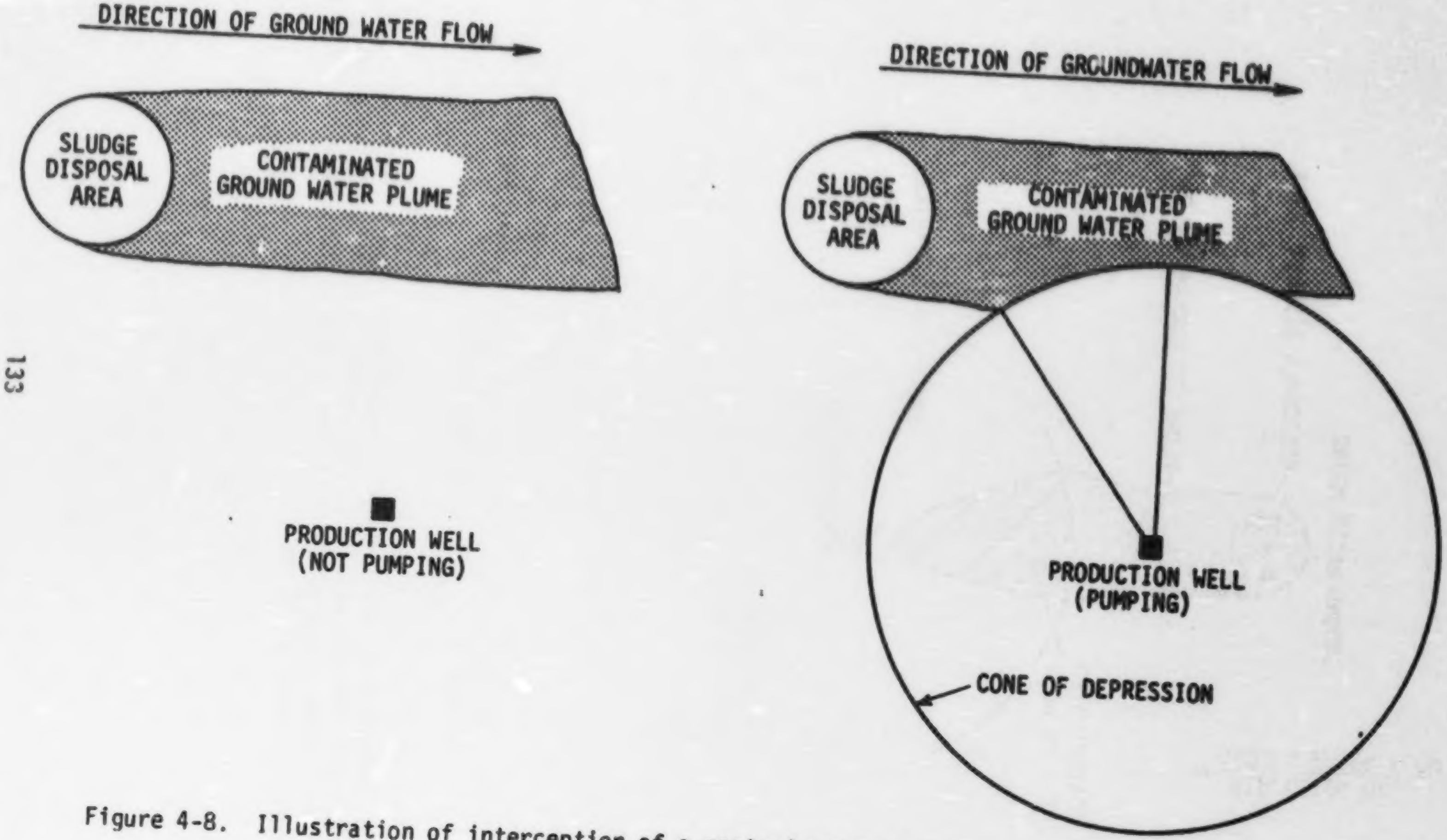

DIRECTION OF GROUND WATER FLOW
SLUDGE DISPOSAL AREA
CONTAMINATED GROUND WATER PLUME
PRODUCTION WELL (NOT PUMPING)
DIRECTION OF GROUNDWATER FLOW
SLUDGE DISPOSAL AREA
CONTAMINATED GROUND WATER PLUME
PRODUCTION WELL (PUMPING)
CONE OF DEPRESSION

Figure 4-8. Illustration of interception of a contaminated ground water plume by a pumping well.

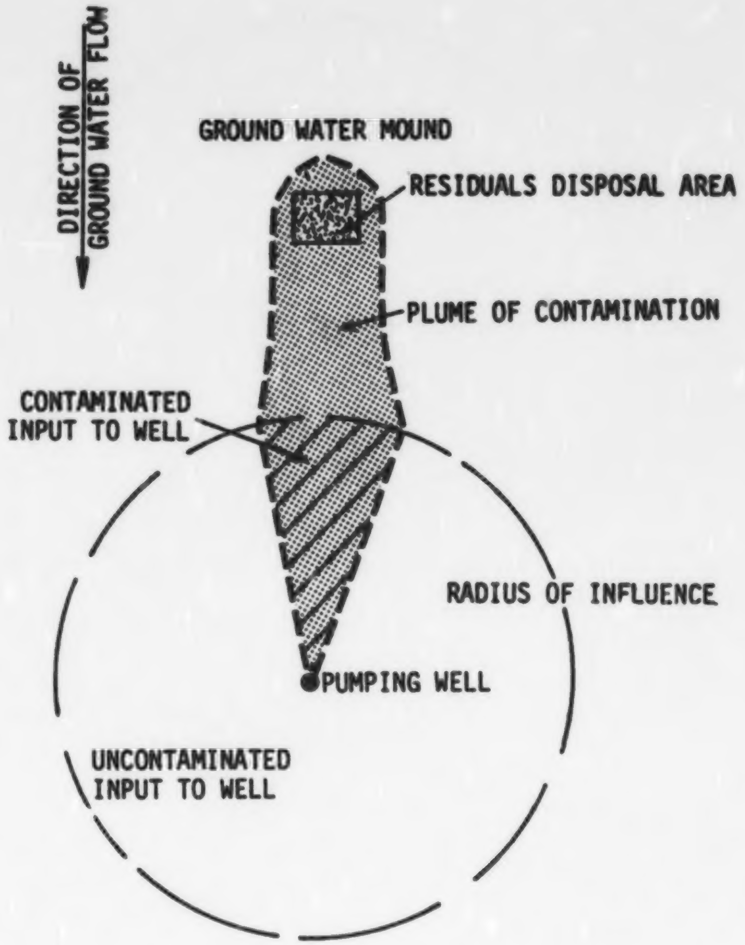

DIRECTION OF GROUND WATER FLOW
GROUND WATER MOUND
RESIDUALS DISPOSAL AREA
PLUME OF CONTAMINATION
CONTAMINATED INPUT TO WELL
RADIUS OF INFLUENCE
PUMPING WELL
UNCONTAMINATED INPUT TO WELL

Figure 4-9. Dilution effects of natural ground water on contaminants from a disposal area[a]

[a] Note that if perhaps the only important contaminant were nitrate, at 2 mg/l as nitrogen, and the nitrate concentrations in the uncontaminated water were 1 mg/l, the blend pumped from the well would easily meet drinking water standards of 10 mg/l.

Since the mathematics of hydraulic boundaries can become highly complex, this discucussion ends simply with an enjoiner to waste management planners to be aware of the possibility that impermeable hills or neighboring streams, acting as hydraulic boundaries, may strongly affect the siting of a disposal area.

4.4.2.5 Ground Water Mounds - A ground water mound is an elevated portion of the water table caused by localized increases in recharge rates due to such external influences as artificial lagoons or irrigation. A sectional representation of a ground water mound is shown in Figure 4-10. Note that the mound extends beyond the periphery of the lagoon. The effect of mounding on ground water flow past the site is illustrated in Figure 4-11. Flow within the mound is radially away from the center. This is imposed upon the natural flow, and the resultant of the two components is as shown.

Since a zone of aeration must be maintained to permit aerobic microbiological activity within the soil, the increase in the water-table level that may be caused by mounding must be considered in site evaluations for disposal by spray irrigation or infiltration-percolation, and in unlined ponds or lagoons. All of these cause mounding by increasing the liquid loading rate over the disposal area.

Mounds may also form beneath landfills. The concern here is primarily with the effect upon subsurface hydraulics rather than with maintaining a zone of aeration. The vertical flow component, as shown in Figure 4-10, may mean that leachate will penetrate to the bottom of the aquifer. Presence of a ground water mound is conclusive evidence of leachate production (Ref. IV-22).

4.4.3 Ground Water - Surface Water Relationships

The belief is common that no contamination of surface waters can occur if residuals are disposed of on the land surface and adequate steps are taken to prevent surface runoff into streams or lakes. That belief is a fallacy. Except in arid regions, streams and lakes usually are natural discharge points for ground water. It is, in fact, this contribution from ground water that maintains the flow of perennial streams between runoff-producing storms. If the ground water becomes contaminated, so will the streams and lakes. The degree of contamination and effects on quality of surface water depend upon numerous factors:

- The travel distance and time between the source of ground water contamination and the surface water body.

- The degree of hydraulic connection between the aquifer and the surface water body.

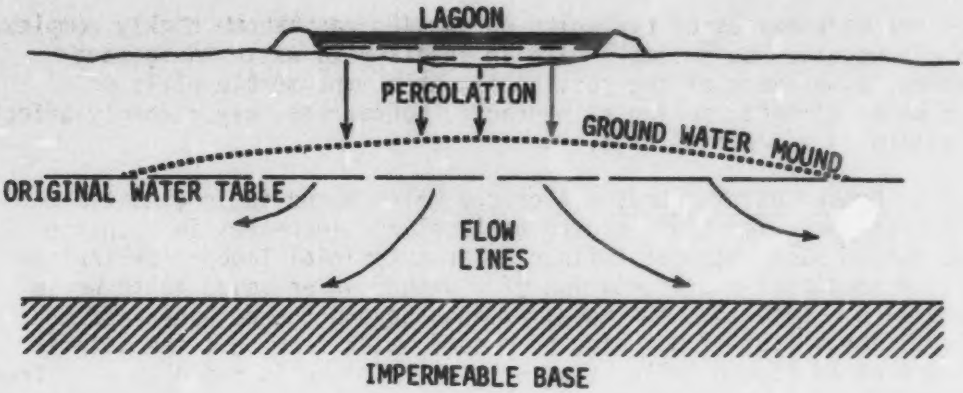

LAGOON
PERCOLATION
GROUND WATER MOUND
ORIGINAL WATER TABLE
FLOW LINES
IMPERMEABLE BASE

Figure 4-10. Sectional view of a ground water mound.

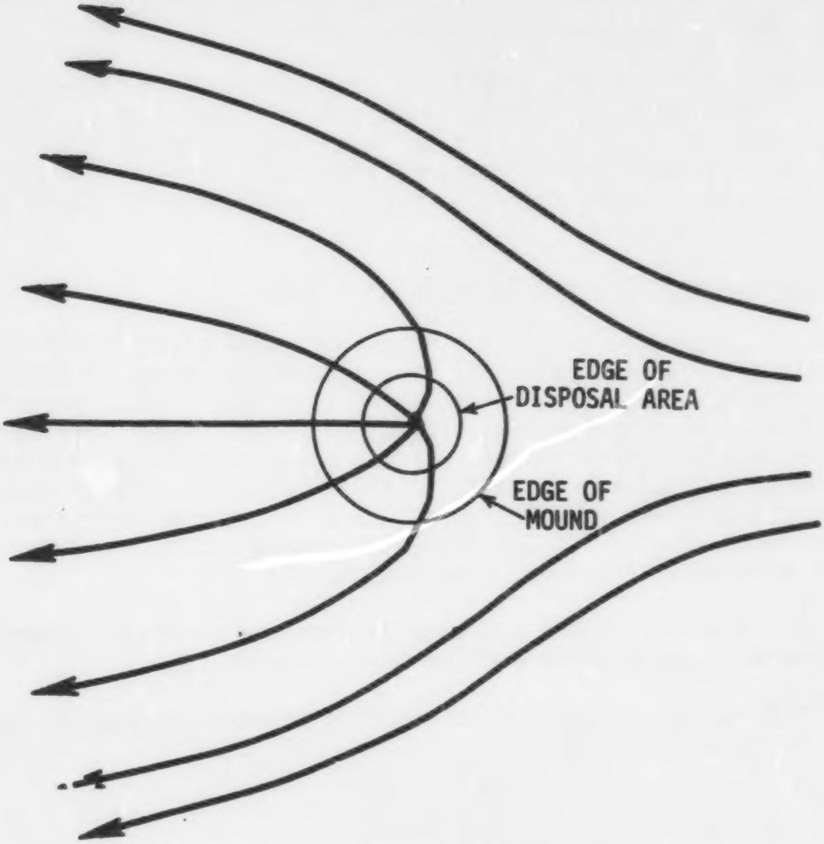

EDGE OF DISPOSAL AREA
EDGE OF MOUND

Figure 4-11. Ground water flow in the vicinity of a mound.

- The nature and quantity of contaminants that enter the aquifer.

- The nature of the aquifer materials.

- The ratio of discharge from upstream sources to the discharge from the contaminated source.

- Pumping wells between the area of contamination and the line of discharge.

- Aquatic biota.

- If the receiving body is a lake, thermal stratification and lake currents.

The range of possibilities is wide. At one extreme might be a case of disposal over an aquifer consisting of coarse quartzitic sand, very near to a stream whose base is low and whose quality is marginal. Trouble will almost certainly ensue. On the other hand, a disposal area over an aquifer containing appreciable silt and clay fractions, located 10 miles from its discharge area (the Mississippi River, say) would not be expected to cause any measurable difference in the water quality of the receiving stream. (These examples do not consider the detailed chemistry of the systems.)

Swamps and marshes constitute ground water discharge areas during much or all of the year. Since there is little water movement within them (in contrast to movement in streams), their biota are vulnerable to the introduction of contaminants. Landfills from which leachate can enter wetlands of any type are particularly undesirable.

In arid zones, the relationship of ground and surface waters is usually different. In such areas most streams are ephemeral, with the water table lower than the bottom of the stream bed, and hence flow only in response to surface runoff. Here, surface water can contaminate ground water. Given a runoff-producing storm, contaminants can be removed by overland flow and transported for many miles, ultimately infiltrating into the ground water beneath the stream bed. These phenomena are episodic, however, rather than continuous and they too are difficult to evaluate quantitatively.

The preceding discussion shows clearly that any site investigation must include consideration of the possibility of contaminating surface waters through ground water discharge. A preliminary assessment can be made from a map study and may be followed by field reconnaissance, all supported by information on surficial and bedrock geology.

4.4.4 Determination of Aquifer Coefficients

If investigation of a potential disposal site seems to require knowledge of the aquifer coefficients mentioned earlier (permeability, transmissivity), they may often be obtained at the nearest office of the U.S. Geological Survey or of the state agency that deals with ground water. If they are not available, the hydrogeologist must perform one or more controlled pumping tests.

A controlled pumping test is simply one that is run without interruption for a specified period (usually several days) at a constant pumping rate, with drawdown and recovery measurements taken at timed intervals. Water-levels are measured to the nearest hundredth of a foot. One or more observation wells are usually required for the best results, and are essential for determination of the storage coefficient.

The value of a pumping test depends largely upon the knowledge and experience of the hydrogeologist who plans and conducts it, and interprets the data obtained. The difficulty of interpretation varies widely, ranging from the simple case of an artesian aquifer with no leakage and no nearby boundaries to the complexities of a water-table aquifer with leakage from an underlying aquifer and with the pumping well affected by one or more hydraulic boundaries.

Analog and digital models are often well adapted to the solution of complex cases, but they are generally most applicable to regional water-supply problems. It is unlikely that the expense of computerized modeling by planners would be warranted in residuals disposal studies, with the possible exception of those involving spray irrigation at marginal sites. In any case, the use of models by no means obviates the need for accurate information on aquifer coefficients, since the reliability of the output depends completely on the reliability of the input.

Some information on transmissivity may be obtained on the basis of specific capacities of existing wells. Specific capacity (not to be confused with specific yield) is the discharge of a well per unit drawdown, usually expressed as gallons per minute per foot of drawdown. If this unit is multiplied by 2,000, it gives an approximation of transmissivity. For example, a well that discharges 500 gpm with a drawdown of 50 feet would have a specific capacity of 10 gpm per foot, indicating an approximate transmissivity of 20,000. The transmissivity values estimated in this manner are almost always too low, however, because specific capacities are reduced by effects of several factors that may not be readily apparent. More accurate use of specific capacities to estimate transmissivities may be found from References IV-23,24.

4.4.5 Geophysical Investigations

A geophysical survey can be useful in delineating subsurface geologic and hydrologic conditions. Success of such a survey depends on having valid subsurface control data and a good understanding of the limitations of the method being used. The two major geophysical survey methods are based on electrical resistivity and seismic refraction. The former yields data useful in both site investigations and monitoring programs; data obtained in the latter method are useful only in site evaluation. The objectives of the proposed survey, therefore, must be clearly defined.

4.4.5.1 Electrical Resistivity Method - The electrical resistivity method depends upon the conductance of electrical current through the subsurface, the measured values of resistivity being inversely proportional to conductivity of the earth materials. For example, resistivity values are low for moist clays and silts and are high for sand and gravel containing good quality water. To measure these values, a known current is introduced into the earth through two current electrodes and the resulting potential drop is measured between a pair of potential electrodes.

Certain conditions that can impair the success of any resistivity survey include poor access to the site, presence of buried conductors such as pipelines or wires, use of equipment not sensitive enough for the required depth penetration, and operator error. In addition, the success of the survey depends on resistivity contrasts between earth materials and/or the ground water contained in the formations. If major contrasts do not exist, differences in the earth materials cannot be interpreted.

Because the measured earth resistivity is inversely proportional to the conductivity of ground water, bodies of water containing high concentrations of conductive wastes will have lower resistivity values than the surrounding natural ground water. Therefore, in some cases the resistivity method also can be used to determine the boundaries of a zone of contaminated ground water. This application, too, may be hampered by certain adverse conditions. For example, if the contaminant does not have a significantly greater conductivity than the natural ground water; if the ground water is naturally highly conductive; or if the depth to water is great, the resistivity contrast may not be large enough to yield useful data. Also, an overly-complex geologic environment would rule out comparison of resistivity values and profiles.

The primary utility of the electrical earth resistivity method in ground water contamination investigations is to provide information on the lateral extent of pollution at a relatively low cost and within a short time. It can also be helpful in the planning of a test-drilling and water-sampling program by eliminating hit-and-miss drilling and thus reducing the required number of test wells.

4.4.5.2 Seismic Refraction - The seismic refraction method of subsurface investigation depends on measuring the velocity of elastic or sound waves within earth materials. Therefore, it is limited to determining the geometry and engineering properties of an aquifer or geologic layer; it cannot indicate differences in water quality.

The velocity of elastic waves propagated in the seismic refraction method can be timed from their initiation to a receptor at a known distance from the energy source. With known velocities and distances, the depths to the various geologic interfaces can be calculated. Where well data are available, they are correlated with results of the seismic survey to provide a refined portrayal of the geologic environment.

The techniques of operation in the field depend on the various applications. In investigation of shallow depths (less than 100 feet), the energy source is usually a hammer blow on a steel plate. For greater depths, dynamite and multiple geophone configurations are used. With the hammer source of energy, the investigator develops a seismic profile by implanting the geophone firmly on the ground and moving the impact point away from the geophone at measured distances. Thus, by observing the energy arrivals for different separations between the impact point and the receiver, he can construct a time-distance curve representing variations of energy travel time with distance.

As the resistivity method depends on resistivity contrasts, so the success of a seismic survey depends on velocity contrasts between earth materials. If these contrasts do not exist, or are slight, the variations between subsurface materials cannot be determined.

The most common application of the seismic refraction method is to determine the geometry of geologic formations. For example, seismic data can be used to determine depth to bedrock and to water, or to map a buried channel or bedrock valley. If can also be used to determine engineering properties and characteristics of the subsurface materials.

4.4.6 Models and Prediction of Plume Extent

Changes in extent and shape of a contaminant plume with time are of interest to planners in cases where the polluted medium cannot be contained. Unfortunately, there is no known method of predicting the shape and extent of a plume for various times in the future, starting from time zero; moreover, it is unlikely that one will become available. The reason is simply that there is no way in which to determine the location, type, and extent of all of the many heterogeneities within an aquifer.

Modeling studies are performed, however, despite these difficulties. One of the most informative investigations of the spread of ground water contamination has been carried out at the (then) National Reactor Testing Station (NRTS) in Idaho (Ref. IV-25). Their findings show the state of the art of digital modeling for such purposes, and demonstrate clearly both the powers and the limitations of the method.

The NRTS site is on the Snake River Plain in southeast Idaho, overlying an aquifer consisting of thin basaltic flows and interbedded sediments, with a water table about 450 feet below land surface. Industrial and low-level radioactive wastes have been discharged to the aquifer through seepage ponds since 1952, and since 1964 cooling-tower blowdown has been injected directly into the aquifer through an injection well. The U.S. Geological Survey has monitored the facilities since their inception, and has analyzed the fate of the wastes, using data from about 45 observation wells. The complexity of the subsurface regime, however, is such that no explanation could be given for past behavior, and no predictions could be made about the future. To resolve these questions, a digital model, simulating the aquifer, was developed. The modeling included a hydrology phase to solve equations for ground water flow, and a solute-transport phase to solve the equation for solute movement, both of which were verified on the basis of historical behavior. The verification procedure was then used to adjust the values of various parameters.

The investigators point to large-scale inhomogeneities in the aquifer as a detriment to effective modeling and caution against extending laboratory measurements to field conditions. They conclude that the model is a valid tool for estimating waste distribution in the aquifer, again warning that this is highly dependent upon future hydrologic conditions, which can only be assumed.

A note of interest to the planner is that the transverse dispersivity value (450 feet) required to give the best fit of the theoretical plume to the observed plume is much larger than had been expected from either classical theory or laboratory models. The actual chloride plume, after 16 years, extended about 5 miles downgradient and had a maximum width of almost 6 miles, as shown in Figure 4-12. In contrast, a transverse diffusity value of only 14 feet has been found in a study of chromium contamination of a glacial aquifer on Long Island (Ref. IV-26).

A current assessment of plume prediction, then, seems to be that values needed in digital modeling can be determined from data collected from a number of observation points over a number of years (both numbers being dependent upon the complexity of the system). These values may then be used to predict the shape and extent of the plume in future years only if it is assumed that there are no major lateral changes in the hydrogeology of the aquifer. Such an assumption may be quite safe or it may be invalid, depending upon the type of aquifer involved and how well its hydrogeology is known.

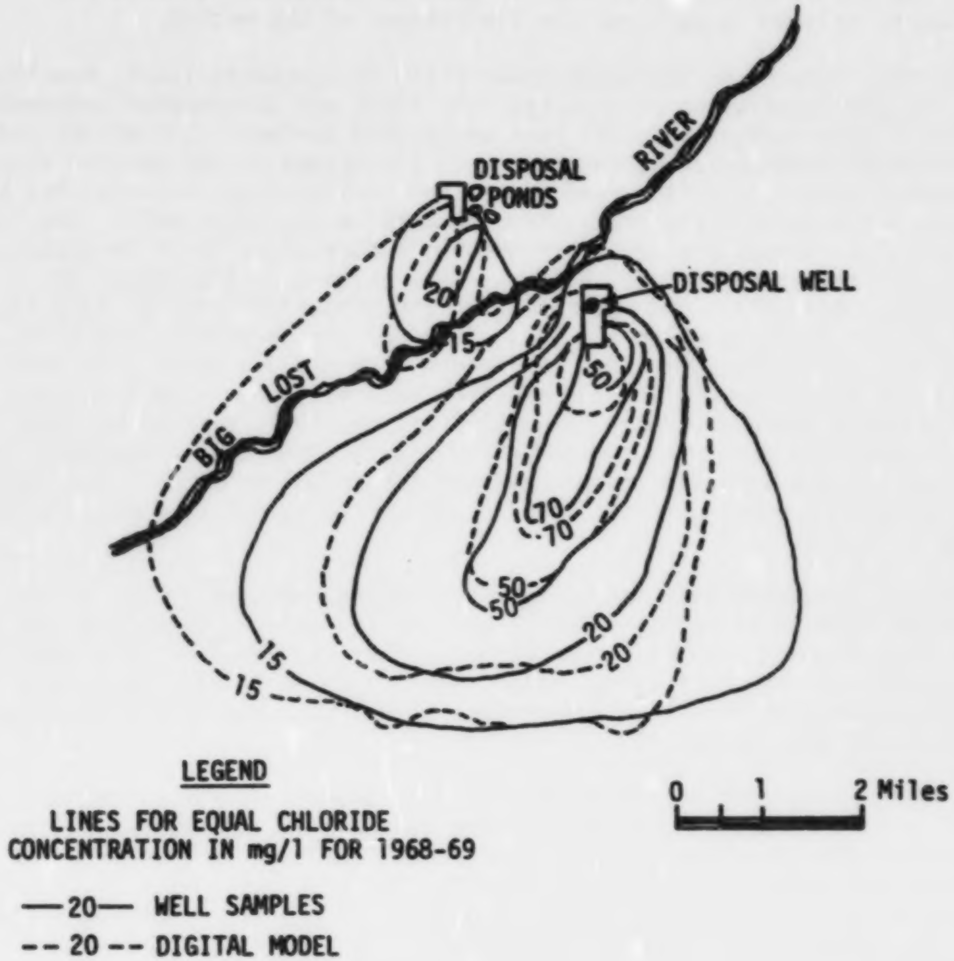

DISPOSAL PONDS
RIVER
DISPOSAL WELL
20
15
LOST
BIG
50
70
70
50
50
20
20
15
15
LEGEND
LINES FOR EQUAL CHLORIDE CONCENTRATION IN mg/l FOR 1968-69
—20— WELL SAMPLES
-- 20 -- DIGITAL MODEL
0 1 2 Miles

Figure 4-12. Comparison of waste-chloride plumes in Snake River Plain aquifer for 1968-1969, based on well-sample data and computer model.

4.5 CHEMISTRY IN THE SUBSURFACE

The chemistry of soil formations at a given site strongly affects the potential of that site for safe and effective disposal of residual wastes. However, detailed descriptions of the many possible chemical interactions and their effects on residuals will not necessarily enhance the ability of the planner to formulate sound decisions with respect to site selection and waste management (see Appendix C). As in other instances cited earlier, the planner will most likely consult with persons having the scientific/technical expertise required to provide a firm base for site analysis and management planning. The discussion that follows, therefore, presents only certain basic and pertinent concepts of soil chemistry, in a manner intended simply to provide a background against which the planner may more fully understand and evaluate the findings of his technical consultants.

Initially, it is important to emphasize that although soil may appear to be an inert, innocuous material, it is in fact a chemically and biologically dynamic medium. The first few inches of soil harbor a wide spectrum of bacteria, actinomycetes, protozoa, and fungi, which function in a habitat of inorganic mineral particles and organic matter. Macroorganisms such as earthworms, nematodes, centipedes, millipedes, and insects and their larvae also inhabit the upper portion of a soil profile.

The soil biota utilizes organic matter contributed by growing plants as a source of energy. This utilization results in decomposition of the organic matter into products of oxidation (carbon dioxide and water) and stable organic residues. The organic residues, in turn, enhance the physical structure of soil by stabilizing aggregates and coating mineral particles. Organic residues are also chemically active.

Minerals comprise the bulk of soil mass; as they are slowly dissolved by infiltrating rainwater, they contribute inorganic elements to the soil biota and to growing plants. The overall results of the interaction of infiltrating rainwater, soil minerals, soil organic matter, crops, and soil biota are measured in chemically characterizing a soil. These components in combination allow for the decomposition of organic substances and recycling of their decomposition products. Inorganic elements are likewise alternatively fixed and made available to plants or microorganisms. It is this assimilative and recycling capability of soil that qualifies it as a natural medium for treatment of waste residuals. The ensuing discussion describes the soil components in more detail and identifies their roles in determining the fate of residual wastes that are placed on or incorporated into soil.

4.5.1 Inorganic Components

Most soils are predominantly inorganic, being comprised of a variety of minerals that fall into three general size ranges: sand (0.05 to 2.0 mm), silt (0.002 and 0.05 mm), and clay determine the textural class of a soil. Plotting the percentages on triangular graph paper will characterize the soil with respect to the given textural fields (clay, loam, silt loam, sandy loam, and others), as shown in Figure 4-13.

Inorganic colloids exert the most influence on physical characteristics of most soils, colloids being defined loosely as particles intermediate in size between particles in true solution and those comprising a suspension (the upper limit on the size of mineral colloid particles is 1 μm). The physical properties of soils depend on the extent and chemical nature of the interfaces presented by the colloids. Shrinkage, swelling, flocculation, and dispersion are surface-controlled phenomena that are important in relation to residuals disposal. Soils containing swelling clays may crack as deep as several feet when dried. Such cracking allows direct migration of residuals downward into the soil profile without an opportunity for chemical interaction with the soil and could lead to a more rapid or larger-scale contamination of ground water than would occur in a comparable nonshrinking soil. Flocculation and dispersion can result in a reduction in soil permeability (sometimes approaching zero) and a general degradation of the characteristics (aeration, structure, nutrient balance) that provide for a "healthy" soil.

More important than those physical phenomena in the relationship of soil and residuals is the chemistry of the soil, particularly with respect to the clay minerals and organic colloids. Clay minerals are secondary minerals formed by weathering of primary minerals or precipitation of dissolved mineral components. In some soils, the colloidal hydrous oxides of aluminum, iron, and manganese have important effects.

The capacity of a soil to adsorb and exchange ions varies greatly with the content of clay and organic matter and with mineralogical composition. This capacity is measured as "cation exchange capacity" (CEC), which is expressed in units of milliequivalents per 100 grams (meq/100 g) of soil (See Appendix C, note C-1). CEC and other properties of soil mineral and organic colloids are listed in Table 4-5. Mineral soils range in CEC from a few to 50 or 60 meq/100 g.

Clay surfaces carry a net negative charge which attracts cations in solution. This adsorption results in a cloud of cations around the clay particles. Because the charges are produced by several mechanisms, the strength and nature of the charges vary from place to place along the crystal faces and edges. The cations, being held with less strength

Table 4-5. COMPARATIVE PROPERTIES OF SOIL COLLOIDS

Property	Humus	Montmorillonite	Illite	Kaolinite	Hydrous oxides
Size (μm)	Subcolloid-visible	0.01 - 1.0	0.1 - 2.0	0.1 - 5.0	Amorphous-microcryst
External surface	high	high	medium	low	high
Internal surface	none	high	medium	none	none
Swelling capacity	low	high	medium	low	low
Cation exch. cap. (meq/100g)	150-200	80 - 100	15 - 40	3 - 15	0 - 5

than that of chemical banding, are able to exchange for one another. Usually the higher the charge on the cation, the more likely it is to displace cations of lower charge.

The significance of a soil's CEC to residual waste management is that cations present in the wastes may be incorporated in the exchange complex and temporarily or permanently immobilized (see Appendix C, note C-1). They also become part of the complex from which plants absorb nutrients. Plant absorption may be desirable as a means of removing certain elements from the system, or it may be undesirable if the elements are in concentrations sufficient to be toxic to either the plants or animals that ultimately ingest them.

The adsorption and precipitation reactions in soil are also affected by soil pH (acidity/alkalinity). Changes in pH cause concomitant changes in clay surfaces which in turn affect the adsorption characteristics and CEC of the clay.

Also affecting the adsorption capacity of soils are reactions of iron, aluminum, and manganese, which form hydroxide polymers known generically as hydrous oxides or sesquioxides. The hydrous oxides have highly adsorptive surfaces, and in many soils and sediments they control the solubility of heavy metals. Under those conditions, the cation exchange reactions are more a function of hydrous oxide chemistry than of clay chemistry.

4.5.2 Elements Subject To Redox Transformations

Some elements that are important constituents in wastes undergo chemical transformations with changes in oxidation-reduction (redox) potential. The chemical reactions may occur as a result of geochemical conditions or as part of normal biochemical cycles.

Probably the most familiar elemental cycle in nature is the nitrogen cycle, shown in Figure 4-14. Nitrogen is basic to life because it is one of the elements in the structure of proteins and nucleic acid. Oxidized or reduced forms of nitrogen undergo a variety of chemical and biochemical transformations. Combustion of nitrogen-containing fuel will oxidize at least part of the nitrogen in the fuel and may also oxidize atmospheric nitrogen if combustion temperatures are high enough. Nitrogen oxides in the atmosphere are dissolved in precipitation and are carried into the soil, where they are further oxidized to nitrate.

Reduction of nitrate or nitrite is accomplished when these species are absorbed by plants or animals and are converted to plant or animal tissue. When the plant or animal tissue dies and is returned to the soil, microbial oxidation converts the nitrogen back to nitrate.

Under anaerobic conditions in the presence of an organic substrate, nitrate is reduced by bacteria to nitrogen gas in the denitrification

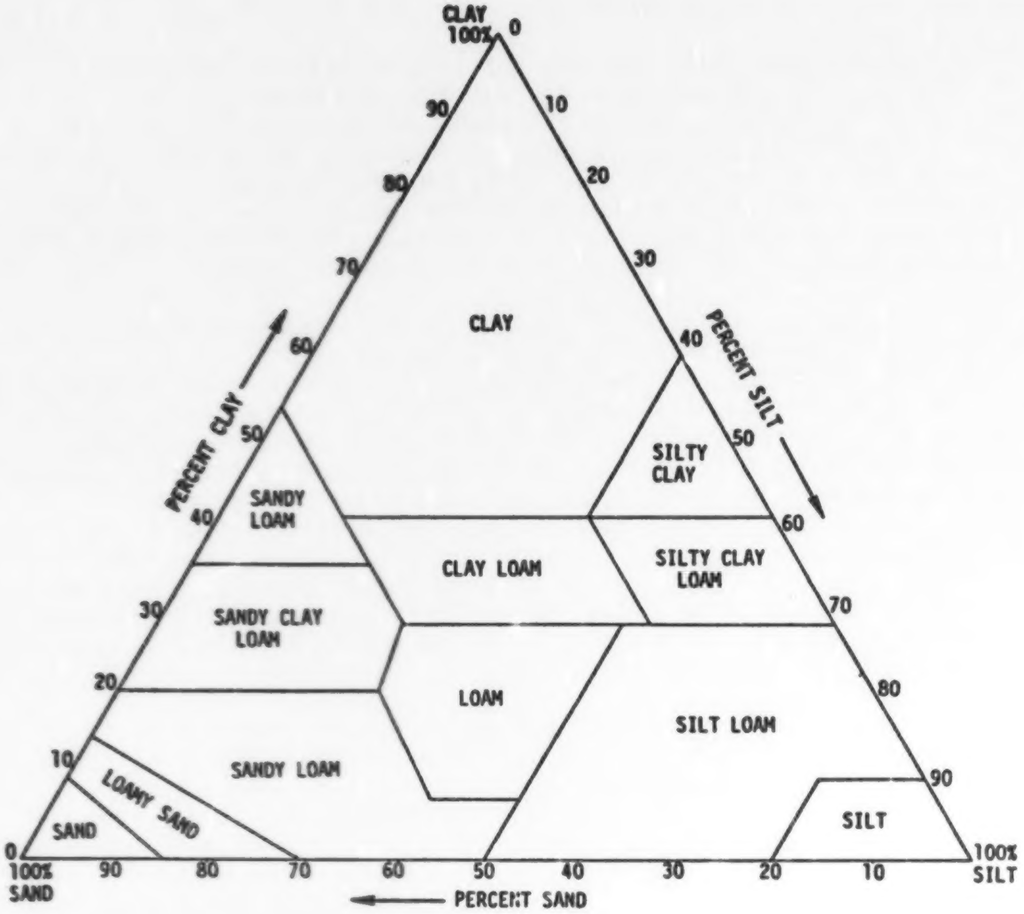

CLAY 100%
0
10
20
30
40
50
60
70
80
90
PERCENT CLAY
PERCENT SILT
CLAY
SILTY CLAY
SANDY LOAM
CLAY LOAM
SILTY CLAY LOAM
SANDY CLAY LOAM
LOAM
SILT LOAM
SANDY LOAM
LOAMY SAND
SAND
SILT
100% SAND
100% SILT
PERCENT SAND

Figure 4-13. Soil texture triangle.[a]

[a] Percentages of sand, silt, and clay when plotted delineate the textural class of a given soil.

Source: Ref. IV-27.

process. This may occur in waterlogged soils (where oxygen diffusion is restricted) or in water. Controlled denitrification in wastewater treatment plants is achieved by developing the appropriate microbial population and injecting a carbon substrate such as methanol.

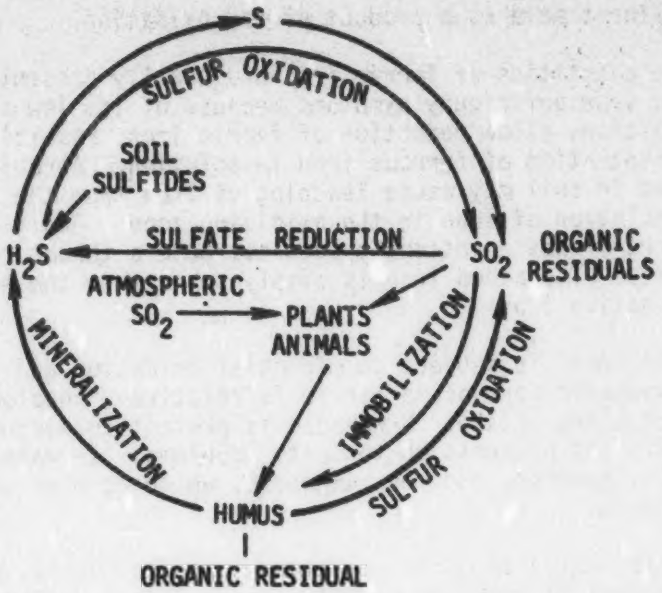
Nitrate forms soluble salts and does not interact significantly with soil colloids. This is important in regard to management of land spreading of residuals containing nitrogen. Nitrate added to soil in excess of requirements for plant uptake or losses by denitrification is subject to leaching and can be carried by percolating water into the ground water system. As a health-protective measure, the U.S. Environmental Protection Agency has suggested a nitrate concentration limit for drinking water of 45 mg/l or 10 mg/l as nitrogen (Ref IV-28).

Sulfur also undergoes geochemical cycling in the biosphere and is subject to many transformations as a result of activities of plants, animals, microorganisms, and man (Figure 4-14). Oxidation and reduction reactions of sulfur compounds affect the reactions of residuals in soil. Oxidation of sulfur or sulfur compounds to sulfate frequently produces sulfuric acid, which affects the soil pH and thus the reactions of heavy metals, which can be made available for plant uptake or leaching. Reduction of sulfate produces hydrogen sulfide, a toxic gas with the odor of rotten eggs. Further, the reduction of iron under the same conditions as sulfate often results in formation of black iron sulfide, which colors soils or water. The production of sulfide in the presence of other heavy metals also leads to formation of highly insoluble precipitates.

Phosphorus additions to soil occur both as inorganic forms and as organic matter in the form of plant and animal residues. Mineralization of phosphorus from these sources closely parallels mineralization of carbon, nitrogen, and sulfur. Although such factors as soil pH, temperature, aeration, and moisture influence the relative rates of mineralization, the extent of immobilization or mineralization depends largely on the carbon:phosphorus ratio. At ratios above 100:1 phosphorus will be immobilized, whereas at lower ratios it will be released (Ref. IV-29).

Iron receives considerable attention as a trace metal that is affected by the metabolic activities of soil organisms. These activities are not always welcome because they may lead to the dissolving of iron from buried pipes or to its deposition on well screens.

Oxidation of iron in soils or water occurs most rapidly when the reaction is catalyzed by microorganisms. One widespread manifestation of the oxidation of iron is the acidic drainage produced by abandoned coal mines and coal spoils. Pyrite, a disulfide mineral associated with coal, is opened to oxidizing conditions when coal seams are disturbed


S
SULFUR OXIDATION
SOIL SULFIDES
H_2S
SULFATE REDUCTION
SO_2
ORGANIC RESIDUALS
ATMOSPHERIC SO_2
PLANTS ANIMALS
MINERALIZATION
IMMOBILIZATION
SULFUR OXIDATION
HUMUS
ORGANIC RESIDUAL

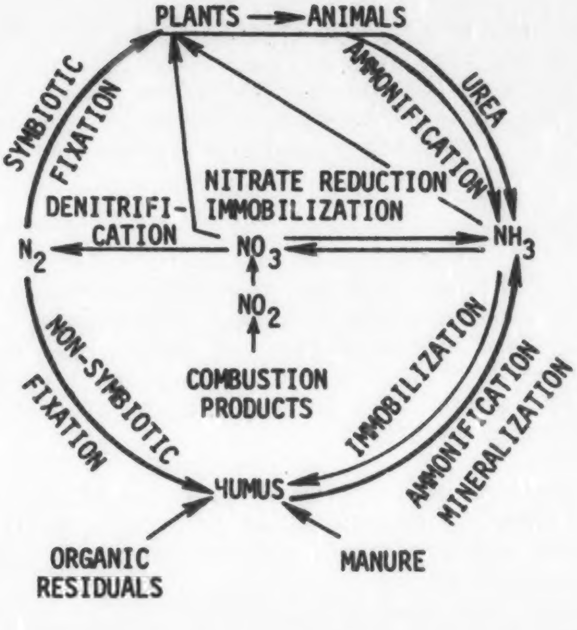

PLANTS
ANIMALS
SYMBIOTIC FIXATION
AMMONIFICATION
UREA
NITRATE REDUCTION
IMMOBILIZATION
DENITRIFICATION
N_2
NO_3
NH_3
NO_2
COMBUSTION PRODUCTS
NON-SYMBIOTIC FIXATION
IMMOBILIZATION
AMMONIFICATION MINERALIZATION
HUMUS
ORGANIC RESIDUALS
MANURE

Figure 4-14. The nitrogen cycle.

and yields sulfuric acid as a product of the oxidation.

Although large quantities of ferric iron are usually present in soils, crops may show iron deficiency symptoms because of its low solubility. Anaerobic conditions allow reduction of ferric iron, resulting in an increased concentration of ferrous iron in solution. Aerobic and anaerobic zones in soil may cause leaching of iron from the reducing zone and accumulation of iron in the oxidizing zone. Addition of iron to soils as part of waste residuals does not pose a threat to fertility or water quality. The added iron is simply subject to the same chemical influences as native iron.

Manganese, like iron, is subject to microbial oxidation and reduction. The oxidized manganic form of manganese is relatively insoluble and unavailable for plant uptake. Manganese is present in agriculturally productive soils and presents no toxicity problems. In waterlogged, anaerobic soils, however, reduced manganese, which is more soluble, may be toxic to plants.

The heavy metals native to soils are known as trace metals, since they are usually present in very low concentrations. Toxic effects are unusual, and deficiencies of the metals required for plant nutrition (manganese, copper, iron, molybdenum, and zinc) are far more widespread under natural conditions. Other common heavy metals include those required for animal or human nutrition (vanadium, chromium, and cobalt) and those having no established nutritional function (nickel, silver, cadmium, tungsten, gold, mercury, and lead).

Heavy metal cations are strongly adsorbed on soil colloids. Quantitative prediction of the fate of heavy metals in soil is difficult because metal reactions do not necessarily follow expected patterns. Particularly important in soil chemistry are the interactions of heavy metals with organic soil components, which are discussed briefly in the following section.

4.5.3 Organic Components

Organic components in soil are derived from plant residues. The process of decomposition includes many chemical steps and usually a variety of soil-dwelling animals and microorganisms. A generalized sequence of decomposition is shown in Table 4-6. Plant components vary in their ease of decomposition, whcih leads to accumulation of certain constituents and rapid depletion of others.

Potentially significant to utilization of waste residuals in agriculture is the formation of humus by decomposition of organic matter. At the humus-forming stage of decomposition, all morphological identity of the

Table 4-6. AN OUTLINE SHOWING, IN A GENERAL WAY, THE CHANGES THAT THE ORGANIC COMPOUNDS OF PLANT TISSUE UNDERGO IN THE SOIL

I. Compounds Characteristic of Fresh Plant Tissue

Decomposed with difficulty	Decomposed easily
Lignin	Cellulose
Oils	Starches
Fats	Sugars
Resins, etc.	Proteins, etc.

II. Complex Intermediate Products of Decay[a]

Resistant compounds	Decomposition compounds
Resins	Amino acids
Waxes	Amides
Oils and fats	Alcohols
Lignin, etc.	Aldehydes, etc.

III. Products of Soil-Decomposition Processes

Resistant complex	Simple end products
Humus - a collodial complex in which the lignoproteinate is considered especially important	Carbon dioxide and water Nitrate Sulfate Phosphate Ca compounds, etc.

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[a] Refers to secondary compounds which are decomposition products of fresh plant tissues or synthesized products of microbial population during the decomposition.

Source: Ref. IV-27.

original plant is gone. The residue, which is in part a product of microbial synthesis, is a high-molecular-weight, polymeric material containing carbon, hydrogen, oxygen, and nitrogen. Humic materials are frequently complexed with clays, and their reactions with metals may also involve clay surfaces. These interactions further exemplify the complex and intimate relationships between the soil components.

A variety of simple and complex compounds are exuded from plant roots, providing a source of organic matter that is usually ignored (Ref. IV-30). The amounts are small, but the influence can be great, since these compounds may complex with metals, rendering them soluble and available for plant absorption. Other such compounds are toxic to some plant species. The production of such compounds appears to inhibit growth of competitive species and thus enhances the competitive advantage of the exudate-producing species.

In recent years soil chemists have attempted to quantify the reactions that occur in the soil and transform or influence chemical species that percolate through it. Soil reactions are dependent upon the activity of microorganisms and the soil colloids and for this reason the extrapolation of results from a specific soil study to predict the behavior of other soils is risky. One approach to the modeling of transport and transformations in soil has been the study of the nitrogen cycle. Laboratory studies with soil columns have measured the kinetics, net gains, and net losses of the nitrogen species, ammonium, nitrite, and nitrate (Ref. IV-31,32). Oxidation of nitrite to nitrate has been studied and mathematically modeled under laboratory conditions (Ref. IV-33,34). Oxidation of ammonium and nitrite with correlation of the population of nitrogen oxidizers has also been modeled under field conditions (Ref. IV-35,36).

The objectives of these studies have been to measure reaction kinetics, the responses of the population of nitrifying bacteria to addition of ammonium and nitrite, and the relative efficiency of biochemical conversions. These data are helpful in the interpretation of field research where controls are less precise than the controls of the models. Whereas the model provides quantitative results for the system being studied, application to other situations is still qualitative.

The sorption of phosphate in soil has been studied, with development of mathematical expressions to describe its behavior. The model simulates phosphate concentration in soil solution and phosphate sorbed on the soil particles (Ref. IV-37,38). The models can be used to determine the response of the soil system to varying phosphate inputs and thus can be applied in planning for waste water renovation by irrigation, or for any other land-spreading disposal of phosphate-containing residuals. There is no record of modeling programs that attempt to simulate the behavior of all chemical species in soils. The complexity of the soil system is greater than that of the surface or ground waters, which have been the subject of solute transport models. A combination of a suite of chemicals already being held in the soil with the many possible physical, chemical, and biochemical transformations renders the soil system less predictable.

4.6 VEGETATION

Vegetation may be used in conjunction with waste disposal for aesthetic purposes, nutrient removal, soil stabilization, or amortization of investment. Aesthetics and soil stabilization often are complementary. For example, when wastes such as fly ash, mine spoils, or dredge spoils are disposed of in piles or mounds, the side slopes are prone to erosion; vegetation can both prevent erosion and camouflage the waste.

A number of residuals contain nitrogen, phosphorus, and other plant-nutrient elements. Discharge of nutrients into surface waters causes blooms of aquatic plants leading to eutrophication. Use of land as an alternate disposal medium allows more profitable utilization of the nutrients. Because nutrients such as nitrate can contaminate ground water, their removal by a crop can increase the total that may be safely supplied to a given site. Crops that produce maximum yields of dry matter, thereby removing large amounts of nutrients, are preferable. Such crops, of course, must be harvested at least once.

Vegetation cover is vital for stabilizing soil against the erosive forces of water and wind. Roots form a mesh that tends to bind the soil; plant stems interrupt the flow of water and reduce its velocity. Some residuals, however, contain salts or chemical elements that may make it difficult to establish vegetative cover.

Another reason for integrating a cropping system or vegetative cover with disposal of residuals is to recover part of the disposal cost. Residuals that contain plant nutrients or have soil conditioning properties can be easily used in conjunction with horticultural or agronomic crops, which can be harvested and sold.

The relationships of vegetation to the several types of residuals is discussed from the points of view of site investigation, crop selection, and crop response.

4.6.1 Effluent

Three application modes are associated with effluent: rapid infiltration (RI), spray irrigation (SI), and overland flow (OF). These differ with respect to the volume and the pathway of the liquid applied, and renovation efficiency (Table 4-7). Sites for RI tend to be depressed to enable ponding of water to maximize infiltration rate. Sites for SI

Table 4-7. REMOVAL EFFICIENCIES OF MAJOR CONSTITUENTS FOR MUNICIPAL LAND-APPLICATION SYSTEMS[a]

	Removal efficiency, % application method		
Constituent	Irrigation	Overland flow	Infiltration
BOD	98+	92+	85-99
COD	95+	80+	50+
Suspended solids	98+	92+	98+
Nitrogen (total as N)	85+	70-90	0-50
Phosphorus (total as P)	80-90	40-80	60-95
Metals	95+	50+	50-95
Microorganisms	98+	98+	98+

[a] U.S. Environmental Protection Agency. 1975

usually are potentially good agricultural sites. Sites for OF are sloped slightly to allow flow, but are not steep enough to interfere with mechanical harvesting equipment.

Infiltration basins for RI of effluent are frequently constructed with a bare soil or gravel-layered surface. Bouwer, however, reports that infiltration rates with a cover of bermuda grass were about 25 percent higher than those in a bare soil basin (Ref. IV-39). The grass cover necessitates special management because flooding must be restricted during the spring growing period.

Vegetation may be desirable where effluent for RI is applied with sprinklers because it reduces disturbance of the soil surface by impact of the drops. Vegetation removes nitrogen and phosphorus from effluent, as it would from any fertilizer. Higher rate infiltration, however, may add so much nitrogen and phosphorus per unit area that the amount removed by crops is insignificant relative to the total.

Spray irrigation of effluent is well suited to the growth of row crops and forests. Application rates can be adjusted to climatic variables and crop needs. The total liquid volume applied by SI is a function of climate and crop type. Some crops tolerate more moisture than others, and some transpire more water.

Pennsylvania State University has sponsored a long-term study of SI of treated sewage effluent on cropped and forested land (Ref. IV-40). Effluent has been applied at various rates ranging from 1 to 6 inches per week. Irrigation periods have ranged from 16 weeks during the growing season on crop land to the entire year in forested areas.

Crops irrigated with treated effluent at Penn State include wheat, oats, corn, alfalfa, red clover, and reed canary grass (Ref. IV-40). Crops projected for inclusion in a Muskegon, Michigan, waste-water study include the cash crops, corn, beans, onions, winter wheat, and legumes; sugar cane and grass crops were used in an effluent irrigation study in Hawaii (Ref. IV-41,42). These examples illustrate the diversity of crops evaluated in regard to effluent disposal.

Yield response at the Penn State site was highly dependent upon the natural precipitation regime. Largest yield increases were noted in years of below-normal rainfall. The maximum increases were 346 percent for corn grain, 130 percent for corn silage, 191 percent for red clover, and 139 percent for alfalfa (Ref. IV-40).

Nutrient compositions of crops from effluent-irrigated areas at Penn State were not significantly better than those of crops grown in non-irrigated, fertilized areas (Ref. IV-40). The irrigated crops do aid in renovation of water by removing nutrients from the soil system and thus from entry into ground waters.

Some crops, especially grasses can absorb more nitrogen and potassium than is required for maximum growth. This phenomenon is termed luxury consumption. In usual agricultural practice, this excess uptake is costly in terms of fertilizer utilization. In the case of wastewater disposal, luxury consumption may be desirable as a means of maximizing nutrient removal. This type of absorption occurs when nutrient loading is in excess of optimum crop requirements. However, too high a loading of nitrogen can also result in excessive leaching of nitrate into the soil profile and ultimately to ground water.

Maximizing nitrogen removal can also be accomplished by choosing crops which utilize relatively large amounts of nitrogen. Coarse grass species such as sudan grass or Sudax (sudan - sorghum) can be harvested up to three times a year. These yield up to 6 tons (dry weight) per year. Corn is another nitrogen-demanding crop particularly if the whole plant is harvested for chopped feed or silage.

Selection of crops for use with wastewater irrigation should be based on their nutrient utilization, tolerance to moisture, and options for utilization. The latter is particularly important if no animals which can utilize the crop are available, or if uptake of such substances as heavy metals restricts the use of the crop.

The microbial population in agricultural soil is large and vital. Bacterial counts are typically ten million per cubic centimeter. In addition, there are fungi, actinomycetes, protozan, and multi-celled animals. Collectively these decompose organic residues added to soils and effect the elemental transformations of the nitrogen, sulfur, and carbon cycles. Adding microorganisms with waste water or residuals usually has little effect on soil because competition and environmental changes bring the added microorganisms into equilibrium with the indigenous population.

Coniferous trees treated by SI at Penn State include European and Japanese larch, two spruce, and four pine varieties. Irrigation aided survival of the trees after planting and increased the growth of larches and white pine (Ref. IV-40). In irrigation of hardwood forests, the younger trees, particularly maples, showed the most growth response.

4.6.2 Sludge

Sludges are the accumulated solids precipitated from municipal or industrial wastewaters. Since most sludges contain plant nutrients, including nitrogen and phosphrous as well as trace elements and organic matter, they can act as a soil conditioner. (A detailed discussion on the characteristics of sludges appears in Section 2.1.)

Sludge is usually land spread by means of tank trucks or wagons. It can also be sprayed through large-bore sprayers, or used in ridge and furrow irrigation.

The relationships between vegetation and sludge is most direct in spreading of agricultural land or areas needing reclamation (see Section 3.0). In these circumstances, sludge is added to promote plant growth as well as to to dispose of the sludge. Other sludge disposal methods are independent of vegetation.

At reasonable application rates, the quantities of nitrogen and phosphorus are sufficient for agricultural row crops or forage. Because potassium is in low supply, researchers suggest supplemental applications. Organic-bound nitrogen and phosphorus are not immediately available to plants but are slowly mineralized with microbial decomposition of sludge organic matter.

Literature on land spreading of sludge has increased greatly since the late 1960's. Recent publications that review various aspects of land spreading include references IV-43 through IV-49, which give details of crop yield responses and chemical quality in relation to sludge application.

Row and forage crops generally respond to sludge in about the same way they would to commercial fertilizer, with perhaps an additional positive response to sludge because of its water content and soil conditioning properties. The latter properties make sludge useful in reclaiming land that has been disturbed for strip mining or any other activity that removes topsoil. In a number of demonstration projects in several states, strip-mined land is being reclaimed with sludge and waste water (Ref. IV-50,51).

One potential problem connected with land spreading of sludge is deposition of heavy metals. Some heavy metals originate in domestic sewage, and from treated urban runoff, but more are added with industrial effluents. Most of the metals present in sludge are not soluble, and after addition to soil, they are not entirely available to plants (Ref. IV-48). Many heavy metals, however, are biologically toxic (e.g., Cu, Cr, Cd, Ni). If not toxic to plants, they may be toxic to the consumer of the crops. Zinc, copper, cadmium, and manganese have been reported as being preferentially absorbed by plants in sludge-amended soils (Ref. IV-46,48). Because the heavy metal concentrations in sludge-fertilized crops could conceivably restrict their use, it is important to include plant analyses in any proposed land-spreading program (see Appendix C, note C-1).

4.6.3 Feedlot Wastes

Cattle on large feedlots produce more manure than can conveniently be disposed of on site. This manure is virtually the same as any other cattle manure, but is too heavily concentrated in one place (See Section 2.7).

Costs of distributing manure are high because it contains plant nutrients in low concentrations. Although almost any crop can be fertilized with feedlot wastes, many of the largest feedlots are located in semiarid areas where little annual cropping is done. Thus transportation costs must be added to distribution costs for disposal by land spreading.

Animal manure, like sludge, adds organic matter as well as plant nutrients to soil. Crops are therefore benefitted by more then nutrient supply, since the organic matter improves soil structure.

Wherever possible, crop production should be integrated with disposal of animal wastes. In this way, nutrients are recycled and the waste dispersed so that it no longer poses a pollution hazard. Corn has been shown to recover 53 percent of the nitrogen, 23 percent of the phosphorus, and 73 percent of the potassium added with fresh steer manure (Ref. IV-52). Crop selection and crop-waste interaction are essentially the same as described under Effluent.

4.6.4 Fly Ash

Fly ash can be added to soils to encourage plant growth. It tends to neutralize acid soils and provides calcium and trace metals (see Section 2.5). On soils that could be treated with gypsum, fly ash is a useful substitute. Use of fly ash as a soil nutrient or conditioner is not generally a major method of disposal (see Section 3).

Vegetation is used in conjunction with fly ash disposal for aesthetic purposes also, since piles of fine-particled fly ash are susceptible to erosion by wind and water. Establishing a vegetative cover protects against erosion and covers the unsightly pile. A soil cover is usually needed for establishment of plants. Species tolerant to high pH, boron, and salt are preferable because roots penetrate the fly ash. Ash piles have been successfully vegetated with well-selected plant species.

4.6.5 Other Wastes

Wastes not now used for promotion of plant growth and not expected to be so used are septage, mining wastes, liquid industrial wastes, and municipal solid wastes (see Section 2.0). Vegetation is used to physically stabilize these wastes or to improve the appearance of disposal sites (see Section 3). Revegetation is one means of reclaiming millions of acres of land that has been degraded by strip mines, spoil piles, and gob heaps from coal mining. A successful revegetation program requires careful planning, knowledge of soils and plants, and sometimes land contouring (Ref. IV-53).

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5.0 LEGAL/INSTITUTIONAL ASPECTS

This section will introduce the State and areawide water quality planner to the legal consequences of alternative residual waste management plans. This information is designed to highlight the need for inclusion of legal and institutional considerations into the planning process. The inclusion of the specific areas of law selected for this section is for familiarity and is in no way exhaustive. The planner, therefore, should consult qualified legal counsel prior to finalizing plans for residual wastes management. The analytical approach used here is: first, to consider the activity a State or areawide water quality management program will involve, second, to determine what possible liability, if any, will result, and third, to provide a legal explanation that will lead to an avoidance of any potential liability and conformance with regulations in implementation of BMP's. The planner should relate this information directly to management practices as described in Section 3 and as applied to BMP's in Section 6.

CONSTITUTIONAL LAW

Constitutional considerations are included to provide a primary understanding to the planner of where various institutions derive their respective authority. It is intended to demonstrate that authority must be founded upon some recognized delegation from the people.

TORT LAW

A Tort is defined as a compensable civil wrong and is sometimes referred to as civil liability. The treatment of this subject is intended to demonstrate how specific conduct can inter-relate or simply interfere with other activities. Again, the discussion does not treat all possible aspects of tort liability; it does point out that legal consequences can and do flow from specific conduct; conduct may be regulated by statute, an ordinance, or by common law principles.

ADMINISTRATIVE LAW

The rapidly expanding "fourth, headless branch of government" plays an ever increasing role in environmental protection. The material on this subject is presented to show that agency, bureau, and commission interaction must be considered in the planning of a State or areawide water quality program, and that rules and regulations form an important part of the law governing residual waste management.

This section of the Planners' Handbook presents a basic core of pertinent law to acquaint planners with legal implications of residual waste management decisions. With this information planners can employ a more complete application of BMP's to residual waste management problems.

Moreover, information is provided the planner with regard to the common law restrictions and the prevalent legislative approaches to solving residual waste problems.

In addition to statutorily created remedies to redress harm caused to the environment, most States have recognized the continuing viability of existing common law remedies. The following paragraphs are examples from current State statutes regulating waste management which retain the common law rights to be exercised by injured parties:

- California law states that new remedies provided in the legislation are in addition to, and do not supersede or limit, any and all other remedies, civil or criminal. Every civil action... brought by the Attorney General shall be in the name of the people of the State of California... (California Water Code, Chapter 5, Article 5, Section 13350).
- Illinois provides that the Attorney General shall enforce the provisions of the act by an action for mandamus, injunction, or other appropriate relief at law or in equity. (Ill. Revised Statutes, Chapter 111 1/2 Section 1022 Environmental Protection Act, Title 5, land pollution and refuse disposal 1970.)
- New Jersey enables the commissioner to institute an action... for injunctive or other appropriate relief when residual waste collection or a disposal facility creates a nuisance condition. (N.J. Statutes Annotated Ch. 39 Section 13: 1E-9 Solid Waste Management Act, 1970.)
- New York authorizes the Attorney General on his own initiative, or at the request of the commissioner or of a private individual, to initiate any appropriate action or proceeding to enforce any provision of this title... or to prevent, restrain the threatened... pollution... or... if the board finds that a nuisance exists, it shall declare the existance of a nuisance... and shall order a suit to be brought in the name of the people for its abatement. (N.Y. Codes Title 27, Section 27-0509, Collection, Treatment, and Disposal of Refuse and Other Solid Waste, 1971.)
- Pennsylvania provides that the department may institute an action in mandamus in the court of common pleas... In addition to any other remedies, the secretary may institute a suit in equity... in the court of common pleas.. where the violation or nuisance exists for an injunction to restrain a violation... (Pennsylvania Statutes Sec. 6016 Solid Waste Management Act, 1968, Amend. 1970 and 1972.)

These examples show that, although administrative authority is enforced through regulations promulgated in response to a law, most of the legislation preserves the right to bring a conventional common law action. In the absence of a statute that establishes new rules of conduct and penalties for violation of those rules, a waste management activity is regulated entirely by the duty of care imposed and other principles of the common law. For these reasons, this legal section treats the non-statutory, as well as the statutory, rights and duties that are associated with residual waste management (Ref. V-1).

5.1 INTRODUCTION TO LEGAL ASPECTS OF RESIDUAL WASTE MANAGEMENT

The conduct of a residual waste management activity (private or governmental) can take many forms and be interpreted in many ways; these depend upon the activity involved and the circumstances surrounding its conduct. Two of the principal factors influencing the interpretation of given conduct are the presence of enacted law, and the existence of established practices (minimally acceptable conduct) being exercised within similar circumstances. The law referred to here may be an ordinance, statute, regulation, or the previous decision of a common law court. These sources of law, supplemented by trade and social practices prevalent in an area, may or may not establish a standard to be met by the activity in question.

The law looks to the facts that are legally significant before it will impose its judgement. Upon taking notice of these operative facts, it looks to the parties involved and determines the character of the conduct that has taken place. The law then looks to the relationship between the parties involved and determines the standard of care to be met by the parties; it considers the existence of any excuse or justification applicable to any of the parties; it then evaluates the resultant harm and concludes by formulating the most appropriate remedy.

In a residual waste management program (as with all conduct), the law seeks to evaluate the "conduct" that has affected the rights of other persons, or their property. A significant factor that must be considered in evaluating certain conduct is whether or not the conduct was the cause of a specific harm and the cause of other effects flowing naturally and foreseeably from this conduct. Once the conduct is defined, then the standard of care to be met by an activity must also be defined; upon this analysis, the probability of liability attaching to an activity can be established.

In seeking to evaluate the conduct of activities within a residual waste management system, the standard of care and rules of conduct will possess elements similar to those recognized in many other fields of activity. For example, all transporters of materials have a duty of care which must be met; it will change when society recognizes the need for varying degrees of care. It follows that handlers of hazardous materials, whether primary, secondary, or waste, are held to a higher standard of conduct than handlers of nonhazardous materials. The standard either arises from the common law or is statutorily imposed; it must be recognized that the common law and statutory law are not mutually exclusive, and that in most cases both will influence the waste management program.

The law imposes liability upon the conduct of activities of which do not meet society's standard of care. To be legally actionable this conduct must be labeled as either: Intentional conduct, negligent conduct, conduct that is negligent *per se* (because it is in violation of a statutory requirement) or conduct that is of such a nature as to make the actor strictly liable, i.e. without the need of proving fault for the damage (engaging in an ultrahazardous activity).

When addressing various aspects of the activities (conduct) associated with a residual waste management system, a planner must be able to employ the best possible measures to effectively implement his program. In the planning of a residual waste management system, statutes, ordinances, and administrative rules and regulations will play a significant role in defining acceptable standards of conduct to be met by the activities within a planner's program. This legal section points out to the planner that it is his responsibility to identify those areas of residual waste management that are and are not effectively treated in statutes and their accompanying regualtions, concurrently, common law considerations must be examined in the respective jurisdictions. This insight can be gained by a thorough research of federal, state and local legislation and of common law decisions applying to a jurisdiction. As a result of this heightened awareness of legal arrangements, the planner will be able to more completely determine what new statutes and regulations, if any, will be needed to enhance the management program.

The publication *Residual Waste: Model State Legislation*, EPA/440/9-76/004, concludes that the effectiveness of a given law or regulation is dependent upon more than just the clarity and comprehensiveness of the official text. The effectiveness of a waste management system is dependent upon the application of available resources and the active support given by the executive branch of State government. Additional strength is created through the enactments of the legislature which express a strong state policy to protect water resources from all forms of waste deposited on or in land. A strongly worded statute will provide little impetus to the waste management system if the executive branch does not request, and if the legislature does not appropriate, the requisite funds to support administration, research, facilities, technical assistance and enforcement. All are necessary elements of an operative and effective regional or local waste management program.

The planner, following his examination of existing legislation must decide whether the current legislation is adequate, or whether new legislation is needed to secure the use of Best Management Practices. *Residual Waste: Model State Legislation* indicates that some States do not need more laws, but do need additional personnel to enforce the existing laws. It goes on to state on page 5-1 that overall effectiveness of one State's waste management program was improved by a modest increase in staff, accompanied by a massive infusion of new interest exhibited by higher level officials of the State. A planner can, therefore, recognize the responsibility placed upon him to evaluate the effect that legislation will have upon a particular residual waste management system. Additionally, a planner must be aware of the need to consider the influence of case law decisions respecting each individual program.

The planner should recognize further that environmental law draws its strength from a mixture of traditional legal concepts. The combinations and interactions of these established legal principles provide to society and to its institutions the capability of redressing the wrongs that have occurred and are occurring to the environment. Environmental law is a delicate mixture of the rules of constitutional law, torts law, civil procedure, conflicts of law, and administrative law. This section of the Planners' Handbook is designed to provide an initial understanding and comprehension of the legal authority relied upon to ensure a sound environment. Not only must the State and areawide water quality planner properly apply state-of-the-art, best management practices (BMP's), he must also be aware of inherent social, political, legal and institutional constraints that will limit his freedom in implementing a water quality management program (See Sections 3 and 6). The planner must understand the interacting special interests of various groups, (i.e., environmentalists, private entrepreneurs, and public service entities). He must, therefore, comprehend the effect that each of these forces will exert on the formulation of a residual waste management plan and its implementation. Essentially, residual waste management plans must be implemented by individuals, groups, and agencies having the responsibility and legal authority to do so (e.g., sewer districts, Corps of Engineers, State enforcement agency, etc.). The planner does not have the authority to implement, but can guide and coordinate the efforts of the implementing agencies.

5.1.1 Taking vs. Police Power

How to site, where to site, and who has the authority to site a facility are all questions to be asked by a planner when implementing a residual waste management plan. The planner must realize that, in addition to the federal government, the State and local governments have recognized procedures for exercising their authority regarding eminent domain and zoning. A search of the applicable federal, State and local legislation by a planner will divulge how the existing laws can be used to facilitate siting activities within his planning area. A planner may discover that land acquired by eminent domain may only be used for a disposal activity if the zoning, at the time of condemnation, will allow such use (Connecticut Solid Waste Management Services Act 1973). Conversely, the planner may find that a State's laws permit even condemned land to be used for waste disposal activities, irrespective of existing zoning, upon a showing of necessity (Illinois Environmental Protection Act 1970). The planner must be aware that eminent domain proceedings can be used to satisfy present and future demands for disposal facilities. Once land has been acquired for the residual waste activity the planner must be aware that the application of the power of zoning ordinances can be used to rezone the surrounding area, thereby providing a buffer zone to protect the facility from future encroachment by non-compatible uses.

5.1.1.1 Eminent Domain - The Fifth Amendment provides that "private property shall not he taken for public use, without just compensation". The 14th Amendment has been interpreted to impose the same obligation upon the States, Chicago, B&O R.R. vs. Chicago, 166 U.S. 266 (1897). Accordingly, when government seeks to "take" property for public use such as a park or a sanitary landfill, it resorts to the power of eminent domain; the property is taken through condemnation, and the owner of the property is entitled to "just compensation". It is well settled that private property cannot constitutionally be taken by eminent domain except for a public use. A planner's understanding of the limits on the use of eminent domain will facilitate establishment of a residual waste management system by government bodies.

5.1.1.2 The Constitutional Power of the Federal Government (Considerations of Eminent Domain and Regulation of Land Use Through Zoning Restrictions) - The Federal government, according to constitutional theory, is a creature of limited authority able to act only on the basis of specific enumerated powers. Thus, even though particular environmental objectives may be within the reach of Congressional regulatory power, the means by which those objectives are attained must still comply with specific constitutional limitations. Accordingly, new initiatives that regulate the use of property or impose criminal or civil sanctions on environmentally undesirable conduct, are likely to lead to questions concerning the "taking" of property.

The potential problem that may arise from the Fifth Amendment's provision that private property shall not be taken for public use without just compensation, is likely to become increasingly important as regulations restrict the use of private property. The line between a constitutional "taking" which requires compensation, and the exercise of "police power", e.g. zoning, which does not, has not been drawn clearly. New interest in a wide variety of land use regulations point to potential conflicts between society's desire to regulate environmentally critical features of land, and private landowners' desires to maximize the economic value of such land.

It is the owner's loss, not the taker's gain, which is the value of the property taken (Ref. V-1). If a landowner could not use his land for any purpose, then his loss would be total; it would be as if government had entered upon the surface of the land and taken exclusive possession. Action in the form of regulation can so diminish the value of property as to constitute a taking. Additionally, environmental regulations should have a rational relationship to a legitimate objective in order to withstand attack based upon equal protection grounds. The selection of a site for a waste management facility must be evaluated by the planner in terms of how he can ultimately gain use of or title to the land. It must be noted that State and local governments have varying procedures to govern the exercise of eminent domain and zoning (Ref. V-3).

5.1.1.3 Zoning - Under the authority of the "police power", the State government may impose restrictions on property that may produce a substantial diminution in the land's value; the Supreme Court of the United States has held that government need not compensate the owner for losses that are incidental consequences of valid regulations (Ref. V-2). Zoning involves the determination by local governments of how local land will be used. The State must confer the ability on cities and counties to exercise the police power, thereby enabling the local legislative body to set up zoning classifications by ordinance. Usually, the local legislative body further delegates participation in this process to appropriate administrative agencies who administer the ordinance and recommend zoning changes. A residual waste management system planner must consider the varying zoning requirements within a particular jurisdiction; additionally, the planner who is versed in the procedures used to change existing zoning regulations will have a valuable tool to assist him in implementing land use requirements of a waste management program.

Various States have taken different positions concerning the question of when the State may exercise its police power and thereby displace local zoning requirements. The zoning authority conferred upon "general law" cities is set out in the State zoning enabling act, and sometimes even in the State's constitution. "Home rule" or "Chartered" cities are not usually subject to the State enabling act because their charter includes a complete delegation of zoning authority from the State. Some charters do not permit pre-emption by the State; other States do permit such preemption in "general law" cities, but not in "home rule" cities. A State and areawide water quality planner must be alert to the possible restrictions that may be imposed by the city and State zoning laws and to use the zoning regulations to his advantage.

The lack of flexibility, encompassed in the traditionally practiced "Euclidian Zoning Process," characterized by strict districting of land, led zoning planners to provide relief in the form of variances and special use permits. A special use permit allows a parcel of land to be used differently from the basic used permitted by its zoning classification, provided such use is compatible with the land and the surrounding uses. Before a variance will be granted, the landowner must show a special hardship caused by the restrictions established by the zoning classification. Administrative agencies in some states have greatly expanded the use of such permits in an effort to achieve zoning flexibility (Ref. V-4).

5.1.2 The Allocation of Roles Between the Federal and State Governments

The Federal Government is increasingly exercising its broad power to protect the environment. Thus, the roles played by the State and Federal levels of government, when controlling pollution that is a concern common to both, must be understood by the State and areawide water quality planner. The scheme of our Federal system and the "Supremacy Clause" of the Constitution unambiguously assign to the Federal Government the superior role by making the Constitution and Federal acts "the Supreme Law of the Land."

The States possess all reserve powers, as expressed by the Tenth Amendment to the Constitution. These broadly encompass the power "to prescribe regulations to promote health, ... good order of the people, and to legislate so as to ... add to the State's wealth and prosperity (Ref. V-5).

When Congress has not exercised its overlapping power in the same area, the question whether such power is vested exclusively in Congress is presented, therefore, potentially barring State attempts at regulation. Where Congress has acted, it must be determined how much room, if any, has been left for further legislation in the same area by the States. The doctrine of pre-emtion normally refers to the latter question, regarding the effect of federal legislation on State power to legislate in the same arena.

To determine the ability of a State to regulate in the absence of Federal legislation, is to ask the question: Is the subject matter of the State legislation national in nature, and does it admit to only one uniform system or plan of regulation? If the subject is national in scope, then the area requires exclusive legislation by Congress. Particularly relevant in the present context, is the Supreme Court's decision in Huron Portland Cement Co. versus Detroit (Ref. V-6). In that case, the Court upheld the local regulation of smoke pollution from ships licensed and regulated by the Federal government, to operate in interstate commerce. The Court emphasized the strong local interest in protecting the health of its citizens. A planner should be familiar with the authority of Federal legislation and when the State and local governments have no authority to act.

Where a State law would otherwise be valid, it may conflict with Federal legislation in the same area. In such cases the Supremacy Clause requires that the State law yield to the Federal law. Where Congress' decision to regulate is made explicit, the pre-emption question is settled accordingly. In most cases, however, courts must decide whether pre-emption can be inferred from a Federal statutory scheme which has not clearly evidenced a Congressional intent to pre-empt. In this case familiarity with court decisions regarding pre-emption will add needed dimension to the planner's residual waste management program decisions.

5.1.3 Civil Liability and Environmental Law

There is a wide variety of enforcement and penalty provisions encompassed by the environmental legislation of the fifty states. States have statutorily identified the parties subject to the legislation and the procedures used to file complaints under the law; furthermore, in some States, e.g. Oregon, there are scales established to determine the degree of imposition of penalties (Oregon Administrative Rules, Ch. 340). The California Porter-Cologne Act has even established a "summary" procedure for seeking injunctive relief and thereby obviate the traditional necessity of having to show an inadequate remedy at law and the danger of irreparable injury in order to receive such injunctive relief. However, the planner of a residual waste management program must be congnizant of the fact that when legislation has not addressed problems, the common law might be used to correct environmental wrongs. The legislation of many States is very complete and has substantially addressed abuses that can occur to the environment; yet again, there are States whose legislation does not completely provide for remedies to effectively reach activities polluting the environment. A planner should possess the knowledge of how potential sources of water pollution can be legally or legislatively attacked; the planner can then better understand how existing legislation and Federal, State, and local adjudication affects residual waste management agencies and facilities and decide if new legislation is needed to address problem areas.

Again, the planner should comprehend what rights are provided by the common law. For example. Oregon Revised Statutes, Ch. 459 states that the remedies expressly provided in the Act in no way derogate from other remedies, such as use of common law remedies. For example, the common law action for nuisance has traditionally been the most common method of asserting an environmental right (Ref. V-7). Familiarity with the concept of nuisance will enable a planner to better integrate the activities within a management program into the activities and institutional arrangements existing in those jurisdictions included within the water quality management planning area.

5.1.3.1 Nuisance - Private and Public - A private nuisance arises from a substantial interference with an individual's use and enjoyment of his property. A public nuisance, unlike the narrow restrictions of private nuisance, may be virtually any form of annoyance or inconvenience to the public at large. The public nuisance action may be brought by the State; however, upon a showing of special injury, different in kind from that suffered by the public in general. The conduct of a waste management activity may also constitute a private nuisance. Some courts treat a substantial interference with a citizen's enjoyment of the natural environment as amounting to a public nuisance. In the City of Miami vs. Coral Gables, 223 SE 2d. 7, 1 ERC 1184 (fla. Ct. App. 1970), the plaintiffs were the City of Coral Gables and twenty individual residents seeking to enjoin the City of Miami from operating a municipal incinerator. The chancellor issued an injunction finding both a public and a private nuisance; the Florida District Court of Appeals affirmed that judgment. In reaching its decision, the court turned to what it took to be the basis of the law:

> Anything that annoys or disturbs one in the free use, possession, or enjoyment of their property is a "nuisance" and may be restrained. No doubt the instant litigation is representative of an assault (semble) by the people of this nation in response to the "crimes against the environment" which have been perpetrated by the users of our amassed technologies. Recognition of the public's right to pure air, soil, and water has been forthcoming from a vast segment of the governmental agencies entrusted to protect these interests for our country's people...

In Department of Health and Mental Hygiene vs. Galaxy Chemical Co., Inc., Civil No. 243-4 (Md. Cir. Ct., decided September 17, 1970), 1 ERC 1660, the plaintiff, the Air Quality Control Division of the Department of Health, sought to enjoin defendant from emitting gas vapors and odors beyond its property lines; in modified form the injunction was granted. This is a classic public nuisance action. The court dealt with the notion of nuisance in the following manner:

> A nuisance is a thing or condition on the premises or adjacent thereto, that is offensive or harmful to those who are off the premises. 1 ERC 1668.

The above noted definition provides the tort of nuisance considerable space in which to develop and adapt to the needs of the times. The tort of public nuisance may be employed to protect from invasion those rights which we hold common as members of the public.

The United States Environmental Protection Agency has identified activities that can potentially cause a nuisance situation in its publication entitled Residual Waste: Model State Legislation, water quality management guidance, EPA/440/9-76/004. Some of these are hazardous wastes, mine drainage, animal feedlot wastes and industrial or mining waste piles (See Section 2). State and areawide water quality planners must anticipate the new problems that could be created and thereby prevent a program from being challenged because of potential injury to the environment. Effective legislation can help ensure proper handling of residuals and prevent the inception of a nuisance situation (Ref. V-8), and the application of BMP's may help correct an existing nuisance problem (See Section 6). Common law actions for nuisance may still be brought by private citizens when they have suffered "particular damage."

Where an entire community is injured in the same manner by the nuisance, public officials have been held to be the proper parties to seek redress. In Kuehn vs. City of Milwaukee, a professional fisherman sued to enjoin the dumping of garbage into Lake Michigan. The right to sue (standing) was denied him on the ground that he was not uniquely injured, i.e., anyone could fish in the lake (Ref. V-9). Experience has shown that public officials, because of inertia, lack of resources, political pressures, or vested interests, cannot always be relied upon to seek redress for a community. Legislation can play a vital role; planners should determine the extent of existing law and consider the possible need for new legislation; the legislation desired should authorize an agency to require the operators of residual waste activities to take remedial action to correct pollution problems which may cause a nuisance situation.

5.1.3.2 Examples of Nuisance Cases - In Karpisek vs. Cather & Sons Construction, Inc. the court, in this action against emissions from an asphalt plant, rejected the argument that this private action could not be maintained because of the number of parties affected, thereby making it a public action. The court relied upon the proximity of plaintiffs to the asphalt plant to distinguish their injury from others (Ref. V-10). Likewise, Wade vs. Campbell indicates that proximity alone to the source of the harm may constitute a sufficient damage upon which to base a suit (Ref. V-11). These concepts could be applied by parties seeking to remedy any harmful effect that could result from the operation of a residual waste management system. In Ozark Poultry vs. Gorman, nine homeowners in the vicinity of a rendering plant sought injunctive relief contending that the odors from the plant were offensive causing them nausea and inability to sleep. The court found the plant to be a public nuisance and ordered it closed unless the conditions were corrected within a reasonably fixed time. On appeal, the Supreme Court of Arkansas additionally found the plant to be a private nuisance. Therefore, this injury could be attacked both by a private citizen suit and by state action (Ref. V-12). A planner, with an understanding of the court rulings in his jurisdiction, can more adequately develop residual waste management planning proposals that recognize standards to which they may be subject.

Simarlarly the Urie vs. Franconia Paper Corporation, a number of real estate owners sued for injunctive-relief against pollution of the river by the paper mill. They contended that offensive odors from the mill affected them all and that sludge and organic matter made the river unsightly and left foul deposits on the riparian owner's lands. The court upheld the right of all of the plaintiffs to maintain the private action (Ref. V-13). Activities of this nature can be analogized closely with harmful effects resulting from a break in a sanitary landfill liner or with ground water pollution caused by improper operation of a residual waste management activity. As to whether or not a citizen will be allowed to sue, the question is likely to be whether the plaintiff has a sufficient stake in the litigation to insure the concrete adverseness on which courts depend for the adequate presentation of issues. This status may derive from personal or economic injury or from damage to an even more intangible interest which the plaintiff has demonstrated as being of great importance to him. The planner must be aware of the effect of these common law actions which often provide the impetus for new legislation that has an even more restrictive effect on waste management than did the common law rule.

5.1.3.3 The Components of Negligence - The negligence concept will play a vital role in determining the direction which a residual waste management program will take. A planner should always consider that the activities of the various components of a management program will have to meet societal standards, and that in non-compliance to the standards, they will be subject to sanctions. A planner must possess the capability of projecting the probable conduct of waste management activities to determine compatibility with neighboring activities. The standard to be met will be defined by custom, statutes and the common law. To be considered negligent conduct must be shown:

1. a duty or obligation, recognized by the law, which requires the activity to conform to a certain standard of conduct, for the protection of others against unreasonable risks.

2. a failure to conform to a required standard. (These two elements make up what the courts usually have called negligence; but the term quite frequently is applied to the second alone.) Thus, it may be said that the defendant was negligent, but is not liable because he was under no duty to meet a standard of care to this plaintiff!

3. a reasonably close causal connection between the conduct and the resulting injury. (i.e., The injury must result from the act and must be the type of injury whose occurrence is foreseeable.)

4. actual loss or damage to an interest of another. (Proof of damage is an essential part of the plaintiff's case. Negligence is actionable only in the case where some individual's interest has suffered.)

5.1.3.4 Reasonable Conduct - Negligence is a matter of exposing another to an unreasonable risk of harm. It is conduct that falls below the standard established by law for the protection of others; this standard, imposed by society, is an external one. Failure to meet this standard, is deemed negligence, even though it may be due to ignorance, forgetfulness or even sheer stupidity. The basis of negligence is not carelessness; the true basis is behavior which should be recognized as involving unreasonable danger to others.

The concept of "risk" necessarily involves a recognizable danger, based upon some knowledge of existing facts and some reasonable belief that harm may follow. The culpability of the actor must be judged in the light of the possibilities apparent at the time. Risks against which the activity is required to take precautions are those which society considers sufficiently great to demand appropriate caution. However, no man can be expected to guard against harm from events which are not reasonably expected to be dangerous; such events are regarded as unavoidable accidents, for which there is no liability (e.g., act of God). A planner must be aware that as the gravity of the possible harm increases, the apparent likelihood of its occurence need be correspondingly less for the conduct to be considered negligent. Stated another way, the more dangerous the activity, the greater is the duty to exercise care.

Handling and deposition of residual wastes entails risks that must be guarded against. Management practices are available to reduce the likelihood of some harmful events from occuring. Failure to employ available methods may involve negligence. In Reinhart vs. Lancaster Area Refuse Authority the court awarded verdicts for negligence in favor of two property owners whose water wells were contaminated by refuse dumped in a landfill which the Authority operated (Ref. V-14). Proper management and containment of leachates may have reduced the likelihood of water contamination in this case (See Section 3.5.2).

Against this probability of the harm, and gravity of the risk, there must be balanced in every case the utility of the type of conduct in question. Certainly it can be said that the utility of a residual waste management system is great in this day of environmental control. The planner must recognize that in proposing the implementation of a management plan, the program must be compatible with other public and private interests.

Foremost among the factors which the planner must consider is the social value of the residual waste management activity; consideration must also be given to any alternative courses. While mere inconvenience or cost may not in themselves be sufficient to justify proceeding in the face of injury or harm, they may justify taking other risks which are not so extreme. It is seldom possible to reduce negligence to a set of definite rules; it is relative to the need and the occasion. Conduct which would be proper under some circumstances becomes negligent under others. The whole theory of negligence presupposes a standard of behavior, yet, the infinite variety of situations which may arise makes it impossible to fix definite rules in advance for all conceivable conduct. The standard of conduct which society demands must be an external and objective one; the conduct which meets the standard of care is the incorporation of a community ideal of reasonable behavior. Regarding a residual waste management system, the standard to be applied is still in a period of formulation; the activities themselves may be establishing the standard to be applied through their own conduct. An awareness of complying to a standard is to be incorporated into the planning process.

Since the standard is a community standard, evidence of the usual and customary conduct of others, under similar circumstances, is relevant as an indication of what the community regards as proper. Community customs themselves are many and varied; some are the result of careful thought and decision; others arise from inadvertence, carelessness, indifference, cost-paring and corner cutting, which are normally associated with negligence. Even an entire industry, by adopting careless methods in an effort to save time or money, cannot be permitted to set its own uncontrolled standard. The holdings in the majority of negligence cases are that every custom is not conclusive of establishing an adequate standard of care. Certainly, the activity's own record of past conduct, (which is commonly called "habit" rather than community custom), is not evidence of a standard of reasonable care.

The EPA recommended Model Law (EPA/440/9-76/004) for residual waste management describes a permitting system that sets standards for a number of waste management operations. Where such laws are in force, they may be regarded as an expression of the community standard (Ref. V-15). Most States utilize a system of permits that provide regulatory agencies with significant authority over a wide range of residual waste management activities. The legislation usually requires the activities to submit operational data, thereby providing information needed by states to establish control over the activities.

The requirement for permits allows agency control over residual waste management by setting restrictive conditions prior to any use of the activity; additionally the permits provide the basis for initiating prompt remedial action. The legislation of the various States defines the application, renewal and revocation criteria. Permit programs can provide a wide scope of control; however, some State permit programs are less effective because of substantial exemption provisions. The permit system provides a structure to assist in defining the appropriate standard of conduct to be met by residual waste activities. A planner armed with the knowledge regarding the effect of permitting programs in his jurisdiction can more efficiently adapt the plan to the requirements which will be imposed upon activities within that water quality management planning area.

The amount of care demanded by the standard of reasonable conduct must be in proportion to the apparent risk. As the danger becomes greater, the actor is required to exercise a commensurate degree of caution. Those who deal with commodities, such as electricity, gas, or explosives, are required to exercise a greater amount of care because of the increased degree of risk. Likewise, a residual waste management system may be expected to exercise greater care when dealing with hazardous waste, than when disposing of ordinary refuse. A planner must take into account the need for a higher degree of care in selecting sites for the disposal of material that may some day penetrate the boundaries of the disposal site.

5.1.3.5 Imposition of Absolute Duty (Negligence Per Se) - It is entirely possible that a statue may impose an absolute duty, for whose violation there is no recognized excuse. The legislature, within its constitutional powers, may see fit to place the burden of compensation for injuries upon those who can measurably control their occurence, instead of upon those who are helpless. In such a case the defendant may become liable on the sole basis of a violation of the statute. No excuse is recognized, and neither reasonable ignorance nor proper care will avoid liability. However, no such interpretation will be placed upon the statute, and no such conclusion reached, unless the court finds that the protection of the complaining citizen(s) was clearly intended by the legislature. An example of how such a statute would read is provided by California's Porter-Cologne Water Quality Act, Chapter 5.5, Section 13385. This provision establishes that: "Any person who discharges pollutants, except as permitted by waste discharge requirements... is liable for the resultant injury." There is no mention that the activities' conduct must be found to be either negligent or intentional; the California act attaches liability to the violator simply upon proof that a discharge will be fined, up to $10,000 for each violation for the damage caused to the envoronment. There need be no actual proof of damage shown by either the State or a specific plaintiff. The planner should consider requesting the enactment of a similar provision in his jurisdiction to simplify the prosecution of persons guilty of promiscuous discharges. This summary approach, as exemplified in the above cited California Act, is increasingly being used by States to attack abuses that occur to the environment.

5.1.3.6 Strict Liability - Strict liability has been said many times to be confined to activities which are extra-ordinary, or exceptional, or abnormal, and not to apply to the usual and normal. There must be a special land use bringing with it an increased danger to others; the use must be more than the ordinary use of land or a use that is proper for the general benefit of the community. The storage in quantity of explosives or inflammable liquids, blasting, the accumulation of sewage, the emission of fumes -- all, have the same element of the unusual, excessive and bizarre; all, have been considered "non-natural" uses; courts may apply the concept of strict liability when these uses result in harm. The place where the activity occurs, the customs of the community, and the natural fitness for adaptation by the premises are each important in determining whether the rule of strict liability applies.

The basis of strict liability goes to the defendant's voluntary behavior which exposes others to risk. The conduct associated with residual waste management occupies something of a middle ground between intentional and negligent conduct. It is conduct which does not depart so far from social standards as to fall within the traditional boundaries of negligence; this is usually because the advantages which it offers to the defendant and to the community outweigh the risk. However, such an activity can become socially unreasonable and the defendant is not allowed to engage in this conduct without having to make good any actual harm which the activity imparts to its neighbors.

In the United States, because of the pressure that was applied to the development of the country's resources, a view point has matured that hazardous enterprises, even though socially valuable, must pay their way and make good any damage they inflict. These activities include: water collected in quantity in a dangerous place or allowed to percolate, explosives or inflammable liquids stored in quantity in the midst of a city, and factories emitting smoke, dust or noxious gases in the midst of a town (See Section 4). The planner should determine, based upon local laws, whether or not the residual waste disposal practices, including the application of sludge to land, and other like activities, are to be considered extra hazardous and therefore subject the operator to strict liability in the event that other persons are harmed. The planner must also take into consideration the long range effects of these activities and the harm that may result years after the closing of an activity. (See Residual Waste: Model State Legislation, EPA/440/9-79/004 Ch. IV Section XVII (A) - (L)). Many State statutes specify requirements that must be met before closing a disposal site. Many other States have not yet recognized the possible harm that can result from improperly closed sites such as continued leaching, gas production, and subsidence. Responding to this need, the Connecticut Solid Waste Management Regulations, Sec. 19-524-9, (1975), define closing requirements and the owner/operator responsibilities that are of a continuing nature after site abandonment. The planner should be aware of methods for completing and using closed landfills (See Chapter 8, Ref. III-39).

5.1.3.7 Anticipating Challenges to Waste Management Siting Decisions - The government exercises control of the environment largely through administrative agencies. Statutes confer the right of a party to bring a particular matter before the court to be heard (standing) to challenge agency decisions upon any party who is aggrieved or adversely affected thereby. In Scenic Hudson Preservation Conference vs. FPC, the court declared that a conservation group had shown that its conservational interests would be threatened by the proposed power plant in a scenic area; this was sufficient injury, without demonstration of any economic harm (Ref. V-16).

The ultimate question in establishing whether an activity is environmentally harmful is to determine if the challenged use is reasonable in view of all the surrounding circumstances; a significant factor regarding the reasonableness of the activity involved would be its location. It is important that the planner not propose facilities, such as a transfer station, or a sanitary landfill in an area already developed for a much higher land use. In the case of and unsightly operation, it would be material if the owner, by use of artifical or natural barriers, could screen the area and thereby reduce the unsightliness of the operation. Similarly, it would be important to establish whether the operators of the sanitary landfill could reasonably conduct their activity without impairing the soundness of the environment. The maintenance of this balance may be dependent upon soil conditions and the proximity of surface water or ground water resources (See Section 4).

5.1.4 Effects of Statutes Upon Standard of Due Care

The standard of conduct required of an activity may be prescribed by legislative enactment (i.e., statute, ordinance, etc.). When a statute provides that under certain circumstances particular acts shall or shall not be done, it may be interpreted as fixing a standard for all members of the community from which it is negligent to deviate. Within the limits of municipal authority, the same may be true of ordinances. The fact that such legislation is usually penal in character, and carries with it a criminal penalty, will not prevent its use in imposing civil liability and providing a gage with which to assess the conduct of waste management facilities.

The courts, through what is termed judicial legislation, advance the public interest, which they find underlying a statute, and which they believe the legislature must have had in mind. Characteristically, the courts have been careful not to exceed the purpose which they attribute to the legislature. The plaintiff must bring himself within a particular class in order to maintain an action based upon the statute. However, the class of persons to be protected may be a very broad one, extending to all those likely to be injured by the violation (Ref. V-17).

5.1.4.1 Negligence Per Se and its Effect on the Burden of Proof - The person who suffers the consequences of another's breach of law may of course recover under the doctrine of negligence per se if he is within the class of persons whom a statute seeks to protect. In Gulf Oil vs. Alexander this doctrine was applied to an environmental harm; a violation of a State railroad commission's rule, that a company should not pollute, was held to create a liability enforceable merely upon its breach (Ref. V-18). So too, in Renken vs. Harvey Aluminum Inc. the court referred to the 1955 and 1963 Federal Air Pollution Control Acts, as evidence of the public's concern with air pollution, in allowing a trespass action by adjoining land owners for past damages to fruit trees and in granting an injunction against further pollution. But negligence per se and other doctrines which derive private rights from public prohibitions have not been uniformly applied. In Renken it was suggested that the public standard would not be used if the legislative remedy could be shown to have pre-empted the field. This notion of official pre-emption has been generally rejected, either because (as in Renken) the statute contained a savings clause, or under the older doctrine that statutes in derogation of the common law (i.e., statutes that would deprive a plaintiff of his normal tort action) should be strictly construed (ref. V-19). In some instances, however, statutes are clearly and expressly limited to public enforcement. For instance, the New York water pollution and air pollution control laws provide that no private litigant may base an action on the provisions of the law or even on successful prosecutions brought under them (Ref. V-20). A planner should realize the value of taking advantage of existing, or of proposing new, negligence "per se" legislation; legislation which permits a private citizen to seek judicial relief against an activity in violation of the statute, would have additional force. When the conduct of an activity is made subject to a negligence "per se" statute, the penalty imposed can be structured so as to place a greater civil liability upon a polluter than the small fines that currently fall upon a promiscuous discharger. Effective redress of harm to the environment is made easier by private parties not having the burden of proving the defendent's activities negligent.

5.1.5 Enforcement Litigation by Public Agencies

In recent years, both State and Federal statutes designed to protect the environment have fared increasingly better in the courts than they had in the past. In upholding State statutes, these decisions constitute a reaffirmation of the broad sweep of the State's police power. Federal statutes have been upheld as falling within the delegated powers of Congress. These decisions reflect a growing awareness in the courts of the need for environmental controls. Thus, in earlier years a New York court could invalidate a city smoke pollution ordinance as applied to a vessel in foreign commerce; yet, years later in a case similar in its cogent facts, the United States Supreme Court, in Huron Portland Cement Company vs. City of Detroit, upheld Detroit's smoke abatement code against the argument that it created an undue burden on interstate commerce. In holding the ordinance a valid exercise of the police power, the Court relied on the legislative finding of the Federal Air Pollution Control Act of 1955 as indicative of both a national concern with air pollution and a congressional intent to leave the responsibility for air pollution control primarily with state and local governments (Ref. V-6 and V-21). Other constitutional arguments and challanges to alleged unconstitutional exercises of administrative power have been rejected in nearly every case in which they have been raised; this has been the result of an exceedingly liberal application of the presumption in favor of the constitutionality of statutes involving the exercise of the police power to protect the health safety and welfare of the general public. Statutes are an important element in the control of residual waste disposal, and the planner should use legislation to advance the objectives of the water quality management program where suitable.

As with the regulatory agencies, planner's first course of action to implement plans through regulatory means is to first exhaust administrative remedies. Failure to achieve adequate results by these means will leave recourse to litigation.

Enforcement litigation presents no legal problems that a well-drawn statute, with an adequate range of authorized sanctions, and an administration which conscientiously follows its terms, cannot cure. However, the effectiveness of enforcement litigation can be limited by several other factors. One of these is the degree of willingness and the ability of the appropriate agency to take action under the statute. Another is the delay caused in the effective enforcement of such laws by challenges based on the constitutionality of such legislation.

Related to the issue of administrative action is the effect to be given to permits, licenses, variances and other forms of administrative approval. A prosecutor must decide whether he wishes to raise in a court of law, questions of the validity or effect of administrative licenses, when the option exists to raise such questions before the licensing or administrative entity. For example, if installation or operating permits for pollution-related equipment are issued or refused by an administrative agency, it may well be that the integrity and coherence of the permit system will be best protected by hearing complaints before the administrative tribunal whenever possible. That tribunal presumably has a deeper understanding of the purposes and details of such a system; the administrative board itself can make the clearest record. This also holds true for a polluter's compliance or non-compliance with the terms of a variance or other exemption obtained through administrative means. This means that rules and regulations, based on enabling legislation, provide a method of enforcement that requires neither the support of the public prosecutor, nor the use of the court system, unless and until the defendant has exhausted his administrative remedies. Given the choice between a law that prescribes specific conduct through rigid sanctions, and a law that delegates control authority to an agency, the latter is preferred. Through a law delegating control enforcement to prevent or remedy environmental abuses, relief can be had without litigation. Such use of legislation can solve many problems outside of the courtroom.

5.1.6 Remedies

Three distinct types of cases have been identified under the heading of environmental litigation. The first is simply litigation between private parties - plaintiff sues for an injury caused to the environment for which defendant allegedly bears responsibility. The second is comprised of prosecutions and other enforcement actions brought by a public agency against an activity for violations of laws and regulations designed to protect the environment. The third, and perhaps only novel category, involves actions by private citizens. Citizens frequently act through organizations established to protect particular environmental interests, against a public agency, either to compel it to take steps to protect the environment, or more commonly, to stop a project or an activity which will allegedly have an adverse environmental impact. Public sentiment and public cooperation will take on new meaning to a planner who is versed in how the populace in his jurisdiction have reacted to interference to change in the environment within their community. To develop this appreciation a planner can look to the past legal actions taken; the planner can then see what obstacles the activities in this residual waste management area face, and he can better understand the basis upon which challenges to environmental change or abuses have been founded. This appreciation of the manner in which legal concepts have been applied to protect the environment will add to a planner's capabilities to achieve an integrated solution to the area residual waste problem.

5.1.6.2 Public Prosecution - In most areas of the United States, prosecution of polluters is only beginning. At the state and local levels, as well as at the federal level, only within the past few years have substantial numbers of government initiated lawsuits been filed to halt or punish pollution-causing activities. These public entities are continually striving to develop the best strategies (combination of prosecution policies and technical assistance procedures) which will be the most effective in abating pollution. Legislation that is not overly proscriptive can be an asset to the planner in providing support to coordinate technical assistance and enforcement measures (Ref. V-22).

The question is less whether or not the government can prosecute than it is one of deciding when all alternative approaches have failed. If prosecution of repeat violators is indicated, the statute should provide for sanctions that will pique the attention of the offender. For example, New Jersey Statutes Annotated, Ch. 40, Laws of 1970, Solid Waste Utility Control Act provides that any person who knowlingly violates the provisions of this Act is guilty of a misdemeanor and shall be punished by imprisonment or fine or both. The Oregon Revised Statutes, Ch. 459, additionally makes provision for suspension or revocation of a facility's license which willfully violates its Act. It is to be emphasized that such stringent provisions are used as a last resort.

"Prosecution" as used here refers to civil and administrative suits seeking injunctive relief, monetary damage penalties, or a combination of such relief against polluters. In many states, there is specific staturory power granted to the Attorney General to pursue such litigation; there usually is no question concerning either the common law or the statutory basis for seeking injunctions and monetary penalties against polluters. A prosecutor acting for any agency of government will give careful attention to all possible basis for seeking relief, whether his support be grounded in explicit legislative enactments, or inferred from the language of statutes and judicial decisions.

Generally, the major objective of government prosecutors is to control existing pollution problems being created by both governmental and nongovernmental entities. The question must be asked by the prosecutor whether an immediate cessation of pollution is desired or whether a gradual cessation should be sought so as to minimize the disruptive effects on the pollution producing activities. Many of the activities causing pollution will have some definite social value, and if it is a municipal waste disposal operation, there may be no immediate alternative to the objectionable practice. An important policy consideration is the extent to which litigation is to be pursued toward obtaining a final judgement, as distinguished from conciliation or settlement. A thinly veiled threat of court action, when supported by a statute such as the New Jersey Code Section noted above, may result in "voluntary" compliance with the regulations.

Prosecution, as desirable as it may appear under certain conditions, cannot be relied upon to achieve the desired results in every instance. As is noted in the Sommers case below, the court may find that the enforcement agency is acting unreasonably. Flexibility, with a balanced program of 'push' and 'pull' is probably the best strategy. Existing statutes or regulations may dictate or encourage compromises that could preclude more stringent enforcement action. For example, California Administration Code, Title 14, Div. 7 Ch. 2, provides that "waivers or modifications of mandatory standards may be made... upon recommendation by the Enforcement Agency and the local land use authority having jurisdiction."

In the case of The Board of Health of the Township of Saddle Brook vs. Sommers Rendering Company the board filed suit to close the rendering operation. However, the court's response was to enjoin the rendering company from using its premises and conducting its fat rendering business in such a manner as to cause the emission and presence of foul and noxious odors in the vicinity of its premises. This relief permitted the plant time to comply to the board's standards rather than completely closing the business. Although flexible with its relief, the court further ordered that unless the defendent immediately remedy certain conditions, it shall cease the operation of its rendering plant altogether (Ref. V-23). In a similar action, Fortin vs. Vitali, the lower court granted injunctive relief to the plaintiff to prevent the invasion of their property by an odor emanating from residuals for composting on the defendant's farm. However, the upper court reversed, concluding from the record that the necessity for such a drastic solution had not been demonstrated. The appellate court determined that a satisfactory means could be devised to abate the situation without requiring the defendants to shut down the composting operation (Ref.V-24). The above cited cases can be likened to the operation of a sanitary landfill, transfer station operation or a sludge disposal program. An appreciation by a planner for the interaction of case law decisions and statutory law will greatly facilitate implementation of a residual waste management program; an activity will then be more compatible with a given community's ability to comply with the plan, based upon the influencing legal considerations.

5.1.6.3 Determining Liability - The threshold question to be asked is whether the alleged invasion is sufficiently substantial to amount to an actionable injury in the eyes of the law. Traditionally, there has existed a notion which may be called equitable cost spreading. This theory, sometimes seen in the case law decisions, contends that everyone has a right to a clean environment; however, in a relatively homogeneous community the benefit of damages collected for each invasion of that right by polluters would be lost in higher prices; this increase in price would essentially compensate an activity for its expenditures to comply with the requirements of community demands; therefore, the cost of the activity's services to the community would correspondingly increase. The argument continues that by allowing the enforcement of the right to a clean environment in these circumstances would require a high cost in time and effort by both lawyers and litigants, with no advantage to the plaintiff in the long run. Thus, the refusal of the courts to entertain these claims results in a net saving to the affected parties and to the community as a whole. However, in most of the cases which come before the courts today, the activity of either the plaintiff or the defendant varies sufficiently from the community norm so that the defense of equitable cost spreading cannot be reasonably applied. Today the right to a clean environment will not always be subrogated to the needs of an expanding economy.

5.6.1.4 Balancing the Utility of the Conduct Against the Gravity of the Harm - This balancing test requires that consideration be given not only to the interests of the person harmed, but also to the interest of the residual waste activity, and to the community as a whole. The utility side of this balancing test includes both the utility to the defendant and the utility to the public generally. In Madison vs. Duckworth Sulfur, Copper & Iron Co., plaintiffs sought an injunction against the operation of a smelting plant whose fumes and pollutants had injured plaintiff's land and crops. The court considered the effect of an injunction regarding the interests of both the defendants and the town as substantially synonmous, "we are asked to destroy ... property worth nearly $2,000,000 and wreck two great mining and manufacturing enterprises, that are engaged in work of very great importance, not only to the owners, but to the state ...". It is, however, important to differentiate the interests of the defendant and the public. The benefits to a private defendant are obtained at the expense of other land owners or members of the public (Ref. V-25). A look at these court decisions by a planner can provide insight into the direction which a community is taking (i.e. Does it favor industry? Does it favor change? Does it wish to maintain the status quo? How effectively is it utilizing statutory remedies? etc.).

When a court deals with an activity which has a recognized utility to the local or national community that is greater than the harm it causes, a permanent injunction is a severe and arguably an inappropriate remedy; by definition the community would lose a net benefit. In some circumstances, a form of abatement which satisfies fairly the interests of both parties may be possible. For instance, it may be adequate to enjoin a heavy duty truck terminal from operating at night when it affects the sleep of surrounding residents, or to restrain low flights out of an airport which cause noise and annoyance to local landholders. Where possible, such a solution is obviously to be preferred, but it is not always available. A planner must be aware of how the jurisdiction within a planning program has balanced the utility of the activity against any harm it causes.

When the best practicable manner of conducting an activity whose utility outweighs its harm still necessarily causes injury, the social balance then points to the award of damages and refuses to issue an injunction. This seems to be the direction in which some courts are now moving. For instance, in the New York case of Boomer vs. Atlantic Cement, Inc., plaintiffs sought an injunction and damages for injury to their property from the dirt, smoke, and vibration caused by the cement plant. The court denied the injunction, finding that the plant was of net social benefit to the public; instead, it awarded damages. Similar rulings have been handed down in a number of jurisdictions (Ref. V-26). Certainly, the above concept can be applied to the utility of initiating a residual waste management system.

Relating to a residual waste management system, Boomer stands for the proposition that in some instances even if residual waste disposal facilities are not totally compatible with surrounding uses, the net benefit of the facility might warrant interference with other citizen's activities.

Once again, the planner must be aware of those legal, social, political, and technical considerations in the jurisdiction to facilitate a recognition of whether the facility in question will (1) impose a "social injury", and (2) whether this injury, according to legal precedents and existing legislation is such that it can be balanced against social utility. If the precedents in the jurisdiction lead to the conclusion that citizen rights outweigh the potential harm that a residual waste facility might impose, the planner will accordingly have to seek new facility sites.

5.1.6.5 The Planner's Responsibilities - The water quality planner is being asked to shoulder a heavy degree of responsibility. He must remember, that he cannot be an expert in all areas, (e.g. the legal profession); he should, however, be familiar enough with the legal implications of decisions regarding a State and areawide planning program to enable him to evaluate the need for a legal response to problem areas and to advise waste management activities to seek legal solutions. A planner should understand the standard which activities within a waste management system are going to be held; it is this standard which is going to be used by communities to evaluate the suitability of the components of a water quality management plan.

Although this legal section has shown only the highlights of legal areas significant to a water quality management plan, it has been emphasized that legislation, and not litigation, is to be preferred in seeking solutions to residual waste management problems. The concept of balancing has been discussed, and a planner is in the position to use the balancing technique both at the planning and implementation stages. The planner's decisions are not simplistic; they involve an interaction of many concerns: the seriousness of the need for a waste management system, the availability of technology, character of existing activities within an area, the economic impact of a residual waste activity upon a community, and perhaps most critical, the dependence upon regulation and other agencies for implementing the residual management plan. The legal considerations can provide solutions to some of the water quality planners problem areas; the use of legislation, both existing and to be proposed, can be a valuable tool to the planner. A planner should understand that every aspect of a state or areawide water quality management plan will not be able to meet all the threats to which an activity will be subject. By carefully considering the role that new legislation can play, the planner will have one more weapon in his arsenal with which to more comprehensively discharge residual waste management responsibilities under the water quality planning program.

5.2 AN INTRODUCTION TO INSTITUTIONAL ARRANGEMENTS

Areawide water quality management planning agencies will be largely dependent upon public and private institutional arrangements and individuals for plan implementation. State water quality agencies have partial implementing capability typically in terms of regulation rather than operating management. Planners must therefore become informed about these constraints to implementation and possible alternative approaches to implementing residual waste plans (See Section 6.4).

Therefore, the institutions referred to in this section are the operating entities that collect, store, process, and dispose of residual wastes. Many entities perform only one of these functions; some perform all of these plus a series of planning and regulatory functions.

From among the many forms of institutions engaged in residual waste management, the two primary categories are public and private. Public institutions derive their authority from enabling legislation to perform the waste management functions and to assess the beneficiaries for this service. The State may ensure adequate level of performance and acceptable disposal through regulations and its duty to protect the health and welfare of its citizens. The private institutions derive their authority from the right of private citizens to enter into contracts.

The simplest arrangements for waste management are the purely private enterprises. As a common example, a farmer allocates some portion of his land as a disposal area to which local residents haul their own refuse; paying a fee to the farmer each time they use this private dump. At the next level of refinement, a private collector removes the trash from residential and commercial areas for a fixed fee and then in turn pays the farmer for the use of the disposal area. Soon there are numerous collectors working the same streets; the city or town then passes an ordinance requiring a license or franchise, and each hauler is limited to a section of the city. Later the health department starts to conduct regular inspections of the trucks and the disposal area to ensure that minimum sanitation requirements are met. All of these developments, including the regulatory functions, do not change the nature of the institutional arrangement - it is still purely a private contract system. The great bulk of residual wastes are managed (if the operation rises to the level of management) under private contractual arrangements.

Public institutional arrangements also take many forms, and often the public and private institutions are combined in arrangements for disposal of residual waste. Common examples of these combinations are found where private trash collectors utilize a municipally owned and operated landfill; alternatively, a district sewage treatment plant may dispose of its sludge or ash in a city or county-owned landfill. Some of the most popular institutional arrangements are described more fully in the following section.

5.2.1 Basic Institutional Arrangements

Unlike most public services, municipal solid waste management is often conducted under a mixture of public and private organizations. Various approaches and combinations of approaches offer advantages and disadvantages to all of the participants. Key questions that must be asked by the planner involve a compatible trade-off among cost-effectiveness, relative levels of service, environmental acceptability, and legal authority for conducting the service (Ref. III-42). Other residual waste management is traditionally and sometimes legally a responsibility of individuals and specific agencies. Management and ultimate disposal may be strictly enforced, but most often is not. For example, generators of industrial or agricultural residuals must find acceptable ways of disposal without regard to formal institutional arrangements as a private responsibility. Dredge spoil disposal, on the other hand, is a formal duty of the Corps of Engineers in its management of navigable waterways. The planner must be aware of these existing distinctions, advantages, and constraints, as well as possible other institutional arrangements available. Some of the most basic forms and their usual variations are described here for the planner. The planner may adapt some to specific cases where applicable. However, the planner may desire to seek new enabling legislation where an institutional arrangement cannot be adapted. In this case, the planner must carefully evaluate the institutional approach desired, efforts required to establish, costs of changing from existing arrangements, and balance expected benefits with costs and efforts of establishing.

5.2.1.1 Private Ownership - Public Use - Private ownership of disposal sites with private or municipal collection is still a common system for management of solid wastes. Most modern landfills are regulated through a permit system, either at the local or State level. Disposal is provided through a private collection service paid for by each resident, or the municipality operates the collection service and pays for it by a tax levy. Private collections may be authorized by a franchise from the city and may or may not be regulated by permits for the protection of the public's health and safety. The current trend is toward more stringent and more pervasive regulatory schemes (Ref. III-42). The private disposal sites are generally open for the public's use, and their operation and maintenance is funded by the imposition of a user fee. Not only are these private disposal areas used by the general public but frequently they are used by local industries and businesses. Without enforcement of adequate standards there may be a tendency to be lax in private opearation and possibly allow dumping of hazardous wastes without the proper safeguards. On the other hand, because user charges are directly assessed, actual costs to the user are visible and more equitably applied. Because of the private ownership aspect, user charges may be higher in order to pay taxes, absorb capital costs, and yield a profit for the owner. However, the owner's requirements for a profit and a desire to be competitive may result in efficiencies that could actually keep user charges lower.

5.2.1.2 Public Ownership - Public Use - In this arrangement, ownership of the disposal area often resides in a single government, i.e., city or county. Both private and public collection services have access to the public facility. Private collectors are assessed tippage fees; a public collector, however, commonly does not pay a tippage fee as such, since the governmental entity often assesses utility charges to the beneficiary of this public service. This disposal facility may be open for public use and may also, by agreement, accept wastes originating in other communities. While this form provides more uniform control and the potential for more acceptable environmental considerations, actual costs of operation are often buried in other budgets. Consequently, increasing costs resulting form inefficiencies may not be immediately apparent. However, because taxes are not paid by a public entity and a profit is not required, overall costs may be lower.

5.2.1.3 Private Ownership - Private Use - As noted elsewhere, in the absence of a regulation directing a governmental agency to collect or dispose of waste in a specified manner, every generator of residuals is responsible for disposing of that which he creates. A major portion of the residual wastes disposed of in this country are generated by private mining, industrial, and agricultural operations, and almost all of these are disposed of by private arrangements. Most of the residual wastes of these activities come to rest on private lands, which are owned, leased, or otherwise contracted for by the generators of the wastes. The disposal methods may be regulated by a public agency, and better management practices will most certainly be imposed upon many such disposal operations, but they are privately owned and operated and are almost always reserved for the private use of the owner/operator. These classes of waste generation are considered more fully under "Special Cases."

5.2.1.4 Mutigovernmental Landfill Ownership - With this arrangement the site is owned and operated under the authority of a single multigovernmental agency (e.g., county-county, city-county, etc.) (See Section 6.4). The facility is used by a number of municipal and private disposal operators located within a reasonable distance from the site. All users pay a fee in proportion to their use of the landfill. In conjunction with the landfill area, intermediate waste transfer stations may also be operated by the multigovernmental agency, again supported by tippage fees. Several cities or sanitation districts may all contribute to the original purchase price of the landfill site. The multigovernmental agency is charged with daily operation of the facility. Tippage fees collected from all users provide a fund from which operating expenses can be drawn; this fund also provides a source of revenue for the purchase of additional disposal sites when the need arises. This method offers economies of scale, but may be difficult to form and to provide uniform management among the various entities.

5.2.1.5 Single Government Jurisdiction with Multigovernment Use - Under this arrangement, use of the facility by several governmental entities is through approval of the lead governmental unit. The lead unit may be the State, county, city, special district or other legal entity used or established upon the consent of the participants. Because of the mutual economic benefits that accompany a large-scale operation of this type, the lead governmental unit may actively solicit surrounding communities to participate in this arrangement. The facility could be supported through users fees assessed to all participating. This method offers economies of scale as well as uniform management. The single governmental entity must possess good management and coordinative skills to both form and operate such an operation.

5.2.1.6 Waste Disposal Utility (Nonprofit Corporation) - In this arrangement the municipalities join together and form a corporation; the cooperating members hold stock certificates and possesses shareholder rights. The utility corporation functions autonomously: it processes wastes, recovers materials, and disposes of the materials that cannot be recovered. The revenues derived from the recovery operation are used to defray the total operating cost; the remaining costs of operation are borne on a per capita basis by the stockholding municipalities. Here again, collection service and equipment may be supplied either privately or governmentally. Municipalities in the Muskegon area of Michigan are using such an institution, and those in the Seattle-Tacoma area of Washington have a similar arrangement (Ref. V-27). Many of the advantages and disadvantages noted before are inherent in this form.

5.2.1.7 Interstate Compacts - Interstate compacts can be negotiated through a River Basin Commission or other large areawide agency capable of assembling multi-state resources to pass individual state statutes for each State involved. Congress must ultimately pass enabling legislation forming the compact. Through mutual agreements all wastes, or possibly only hazardous or toxic wastes are finally disposed of by two or more States at an environmentally safe disposal site located within the boundaries of one of the cooperating States. The incentive for the State receiving the waste is that the entire region, of which the receiving State is an integral part, will enjoy cleaner water as a result of this areawide disposal plan. Without this arrangement water quality could be substantially degraded. The disposal site under the jurisdiction of the interstate compact may be privately or publicly owned.

Interstate compacts are not to be regarded as offering an "easy" solution to the common problems of an area composed of segments of contiguous States. The time and effort required to obtain passage of a statute by U.S. Congress, is probably beyond the resources of even a bi-state areawide planning agency. Where such a compact is in existence, such as the "Tahoe Regional Compact", the functions to be performed in waste management may already be prescribed in the legislation establishing the Regional Planning Agency (Ref. V-28). Moreover, multigovernmental functions operated jointly over State boundaries may be implemented through other mechanisms (See Section 6.4).

5.2.1.8 Regional Systems (Within a Single State) -

State-Operated Disposal System - The arrangement now conducted in the State of Connecticut, in which the State owns and operates facilities for materials recovery, conservation, and disposal, may be the form of many arrangements to come. It provides both the essential economics of scale and the borrowing power required for operation of new, advanced-technology systems.

Special Districts - A number of cities and counties may form a "special district" with powers to levy taxes and to provide solid waste or sludge management services for a wide area. The State of California, for example, places a growing emphasis on area-wide planning and the use of special districts. As stated in the State Controller's Annual Report concerning Special Districts of California, a special district is a legally constituted governmental entity, which is neither city nor county, established for the purpose of carrying on specific activities. It may cover only a small portion of a city or county, or may encompass several cities or counties. Its territory may be contiguous or non-contiguous. It may be limited to a single function or may perform several functions. The governing body may be the Board of Supervisors or the City Council of the county or city within which it is located, or it may be composed of elected or appointed members. The primary consideration is that within the limits provided by the State constitution and State law, it should be autonomous and have corporate and continuing life.

The general governmental powers are substantially the same for all special districts and are shared by most other local governments. Some of the most common powers are: to have perpetual succession; the power to sue and be sued; to acquire real or personal property of every kind or any interest therein; to exercise the right of eminent domain; to appoint and employ necessary employees; to employ counsel; to enter into and perform all necessary contracts; to adopt a seal and to tax. Depending upon the statutes under which it is formed, a district may also have the power to adopt ordinances where violations are punishable by law and the power to float bond issues. The planner should weigh the advantages of special districts with their negative aspects before considering the use of this institutional arrangement. Special districts are often nearly anonymous entities with which citizens are often ignorant of both the existence and the type of services they deliver. They represent extra layers of government and often, an unnecessary increase of public employment. They comprise another level of government with which other units must coordinate, and there can possibly occur a duplication of efforts by co-equal levels of government. These arrangements often result in an increase in the total cost of government, demanding an increase in taxes and an increase in the cost of collecting these assessments, much of which comes from the property tax base.

State Financing of Public and Private Facilities - State financing of local entities is also a possible alternative for a state-controlled system. For example, Arizona law includes a provision for State financing for resource recovery facilities and pollution abatement equipment, all within existing institutional arrangements (See Section 6.5).

5.2.1.9 Cost Plus Fixed Fee (Arrangement between Local Governments and a Private Contractor) - Another disposal management possibility is a contract with a private firm to operate the collection and disposal facilities on a predetermined "cost plus fixed fee" basis. Either the government or the contractor may own the collection equipment, the facility equipment, and the disposal site. Some cities currently contract their mass transit and fire protection services with private contractors, and many government agencies participate in a "facilities management contract" under which a private company operates their computer system (ref. V-29). Similar arrangements could be applied to waste disposal services.

5.1.1.10 Public Marketing of Waste Products - Among arrangements for disposing of reusable municipal residuals, the City of Milwaukee, Wisconsin, sells or donates wastewater sludge to local farmers for spreading on farm land. Milwaukee has also been involved for several years in drying and bagging dried sludge as a fertilizer product called Milorganite. While sludge produced exceeds Milorganite sold, benefits are received from spreading upon County parks and offsetting some treatment and disposal costs. Some smaller municipal wastewater plants have successfully "sold" sludge to local farmers, but a much larger number are satisfied to donate the material to farmers who will receive it.

5.2.2 Special Categories of Waste Generation

The generators of residuals from dredging, mining, wastewater treatment and certain industrial and agricultural activities are responsible for disposal of all wastes resulting from their operations (See Section 2.0). Some of the special institutional considerations related to such special cases are discussed here.

The generator of residuals often makes provisions on an ad hoc basis for disposal of intermittent loads of waste materials. For example, the local "sponsor" (e.g. port district or levee board) of a Corps of Engineers harbor improvement project is charged with finding an appropriate disposal site before the dredging begins. Privately sanctioned dredge projects, usually operating in compliance with a permit; also must find appropriate and approved disposal sites. With both the Corps and private projects, if private property is to be used for disposal of the dredge spoil, contracts must be arranged with the owners of the private land before deposition can begin (See Section 6.6.9).

Industrial operators often dispose of wastes into a public sewerage system; an assessment is placed upon the discharger based upon the biochemical oxygen demand (BOD) or chemical oxygen demand (COD) loads per pound that are discharged into the system monthly (See Section 2.6). As these sewerage systems become incapable of handling such excess loads, however, the charges will increase and greater restrictions will be placed on the types of material that may be discharged. Many industries will then elect to arrange for private disposal or will start to preprocess their effluent (the preprocessed effluent still may be a problem). The generator of industrial wastes often acquires a right (as owner or lessee) to land contiguous to his industrial site and uses that land as a private dumping area; such use requires a permit in some states (See Section 6.6.6).

Mine tailings represent a significant part of the total volume of residual waste (See Section 2.8). Although regulatory bodies show growing interest in controlling the leachate from these waste piles, the management agencies with which regional planners must work are usually the private mining companies.

Many waste piles are located on land long abandoned by the mining companies, sometimes referred to as "orphaned land" and often administered by a special State commission. In this situation, an antileaching regulation has little effect if no group or institution can be held responsible. Innovative management approaches are needed to place these waste piles within the jurisdiction of an institutional structure that has both a vested interest to protect the environment and the technical skills needed to solve the drainage problems (See Section 6.6.8).

As a final example of the special-case waste generator, even a municipality is held responsible for disposal of its own residual sludge (See Section 2.1). In some instances other government entities, such as a solid waste department, may be able and willing to accept the sludge. If this is not the case, the residual waste problem is compounded, and the local wastewater treatment plant, like the mine operator and the dredger, must find its own solution. As mentioned earlier, private contracts are often arranged for disposal of sludge by farmers. In recent years, some treatment plants have established their own landfills and land spreading sites, e.g., Blue Plains for metropolitan Washington, D.C. and Fulton County Prairie Plan for metropolitan Chicago; these facilities are integral parts of the waste management institution (See Section 6.6.1).

5.2.3 Relationships with Existing Institutions

In examining long-term site and facility requirements for safe disposal of residuals, the State or areawide planner will be working closely with personnel of the existing waste management and related institutions.

The planner will be assembling data on present and future waste loads and possible disposal options for the classes of residuals that represent a water quality problem in his region.

The State and areawide water quality planner, specifically, is charged with determining the magnitude of water quality impact from each of the residual waste sources that is identified as a problem; selecting and recommending to those responsible for impelmentation the Best Management Practice that will bring these sources under control, and determining the need for new legislation or intergovernmental agreements to implement the recommended BMP (See Section 6.0). Usually the planner will be constrained to work within the framework of existing institutions, perhaps engrafting onto them the additional functions or territories required to satisfy the needs of the entire planning area. In other situations, existing approaches and institutions will be so inadequate that the planner must innovate in order to effect a successful application of BMP's. This may require modifying the existing institutional structure, or possibly the creation of a new arrangement.

Historical practices in a given area and the political power of the entities (private and public) that are currently managing the residual waste activities will strongly affect the formulation of a workable (and acceptable) institutional arrangement. One of the first obstacles that a planner may meet is resistance of the local body politic to changes (in any form) that may reduce or abrogate its influence. A key to success, therefore, may be the degree to which water quality problems can be resolved by expansion or minor reshaping of existing institutions. Although it is inevitable that some provincial policies will have to give way, the planner must actively educate, coordinate and seek consensus (See Section 6.6).

In an area that has a well-organized multicity sanitation district that has handled the disposal of solid waste and the sludge for many years, the planner will be concerned primarily with those portions of the area that are not part of the "sanitary district". In regions where rapid growth has occured and institutions are not keeping pace, the planner may be faced with the need to develop a completely new institution.

5.2.4 Structuring a New Waste Management System

A completely new institutional arrangement would be considered when numerous small systems must be combined to operate effectively. A new arrangement might also be considered when the changes required for the existing management system are so extensive that a fresh start is needed to prevent a "patchwork" solution (Ref. VI-2). A new arrangement may call for passage of new ordinances or statutes, creation of a new organization to operate facilities, definition of the limits and powers of the institution and formulation of effective contractual relationships between government units or between governments and private bodies.

The structure of a new institutional framework must take into consideration the following factors:

- Mobilization or collection of residual wastes, areawide.
- Acquisition of competent technical and management services.
- Selection of the most appropriate and cost-effective transportation channels.
- Development of a system of incentives to promote the reduction of waste loads and to provide for complete utilization of waste products.
- Financing of new capital improvements.
- Funding of the recurring operating expenses and amortization of capital improvements.
- Assurance of comprehensive planning arrangements to meet future needs.
- Participation of the constituency of the proposed service area in the planning and decision-making process. (This consideration is principally important with respect to the pricing of services and products and the development of an equitable scheme for distributing the cost burdens).
- Provision for the adequate research and system development.

The planner must perform activities related to all of these considerations in an atmosphere of good faith and cooperation. The various governmental, private, and industrial groups and individuals that will be affected by the new institutional arrangement must be motivated to cooperate to achieve the common goal: maintenance of water quality through environmentally sound practices. The planner must keep all participating organizations abreast of current progress and of changes that affect the parties concerned. The planner must also make provision for any required clearances of a local Agency Formation Commission or by any other State body (Ref. VI-8).

5.2.5 Additional Factors Affecting Choice of an Institutional Arrangement

5.2.5.1 Existing Statutes for Intercity Cooperation - The existence or nonexistence of a State statute providing for the creation of "joint powers agreements" or of "special districts" will greatly affect the planner's line of action. Although both of these approaches can be very useful, the lack of an enabling statute may preclude such a solution (See Section 6.4).

Legislative provisions that vest power in "Home Rule" or "Chartered Cities" may result in such cities closely guarding their power to solve their own problems. Depending upon precedent, however, such legislation may significantly assist in developing a new structure because such cities may have the power to enter into joint powers agreements with other entities. The ease with which a new statute can be enacted to empower the establishment of a multicounty type disposal operation may control the rate of implementation. The State of Minnesota has passed such an act for the five-county Twin Cities Area and thus has created a new institution capable of coping with the areawide problem of solid and sludge residuals disposal (Ref. V-30).

In the event that a novel, intergovernmental institution appears to offer the most cost effective solution to an area's residual waste disposal problem and the entities do not have authority from the State to enter into some form of agreement, a new law will be required to "enable" the municipalities to cooperate. The procedure that is generally followed is to enlist the aid of a member of the state assembly for your district who is then assisted in drafting a bill for enactment by the State legislature. Such an enactment could create a new entity spelling out all of the powers and duties delegated by the State, or it could simply delegate to the municipalities the authority to work out an agreement to their liking.

5.2.5.2 Need to Acquire New Disposal Sites - If the current institutional arrangements are primarily private, and if sites for new facilities are not available for sale within an economical hauling distance, the power of eminent domain will be required to obtain the needed sites. Although it may be possible to use the power of eminent domain to condemn and pay for land required by a private operator to serve the public purpose, it is almost always easier to exercise this power on behalf of a public entity to serve the same public purpose.

5.2.5.3 Desire of Local Government to Short-Cut State Requirements - In jurisdictions where State-level approval of special districts or similar arrangements are difficult to achieve, intergovernmental service contracts might offer a simple solution. Most States permit such a mechanism (See Section 6.4). Some economies of scale may be achieved by entering into a contract with a larger, neighboring county or other entity for disposal of the area's wastes. Ongoing operation of an effective system and the availability of suitable disposal sites are assumed. The cost sharing of research and new high-technology resource recovery systems could make this option mutually beneficial.

The negative side of this option is the probable resistance of an existing waste management agency that might foresee its influence and future growth being diminished by such a plan. If such an agency is well entrenched, contracting might not offer an easy solution.

5.2.5.4 Need to Increase or Avoid Debt Limits - Capital requirements and the proximity of a government or agency to the limits of its permissible bonded indebtedness could be important. If State laws or constitutions limit the borrowing power of cities and counties, the local governments might opt for either a privately owned and operated disposal operation or a franchised public utility (privately owned or owned by the using governments). In this way they might either avoid a capital investment or undertake the investment jointly but avoid the new increment of proscribed public debt (See Section 6.5).

5.2.5.5 Availability of Skills - Lack of personnel who are skilled and experienced in waste management may dictate contracting with another government (currently operating a disposal facility) or with a private firm to manage the residual wastes disposal program.

5.2.5.6 High Cost Resulting from Labor Intensity - Waste management has traditionally been labor intensive. In recent years this factor has compounded already skyrocketing cost of waste disposal functions in some of the larger metropolitan areas of the nation. Private firms contend that they are able to contain costs better than publicly-operated waste disposal systems. Therefore, they seek to encourage local government to contract this service to them to save costs and provide efficiencies. Many local governments, on the other hand, insist that private firms are beset by the same problems as government in terms of labor activism, growing wage and pension costs, and maintaining efficiency. Nevertheless, private firms are enjoying a growing share of waste management activities. Industrial waste collection and disposal is primarily conducted by private firms (See Section 2.6). This is likely to be extended to management of other residuals. Government's role is to ensure that this service is provided equitably and properly.

5.2.5.7 Governmental Subsidies to Private Entities - Where the economics of resource recovery are marginal, areawide or local governments may provide a partial subsidy to a private entity both to reduce waste loads in landfills and to encourage recycling in the long term. An example of this is the Minnesota Abandoned Vehicle Act, wherein the State pays to the scrap metal company the difference between the value of secondary materials recovered and the cost of salvage operations. Another subsidy, in the form of low-cost or free combustible scrap materials, is provided to power companies that have converted their boilers to burn the low-Btu residuals. This form of "institutional arrangement" between a local government and private utility is exemplified in St. Louis, Missouri.

5.2.5.8 Using Regulations to Implement Plans - The planner is usually well-aware of how regulations can be used to implement plans. It has been established practice to implement land use plans, the official map, and housing quality with zoning ordinances, subdivision regulations, and building codes. These tools may be applied to residual waste management in some cases as well (See Section 5.1.1). Initially, the planner will probably be dependent upon existing environmental laws and regulatory agencies to implement plans (See Section 5.1.3). Changes should be recommended by the planner if existing laws, regulations, administrative procedures, and institutional arrangements are not compatible with plan implementation. The role of the citizen participating as planning advisory members or public interest groups will be important to the planner in these situations.

The planner should recognize that clearly drafted enabling legislation, lucidly-derived regulations, and skilled administrative procedures will not necessarily solve the problem of plan implementation. A case filed on January 16. 1976, State of New Jersey, Department of Environmental Protection vs. J.I.S. Industrial Service Company illustrates that even with seemingly clear statutes and regulations, significant problems in prosecution can be encountered. In this case, the State has alleged that hazardous wastes being disposed in a landfill is contaminating the aquifer through leaching (Ref. V-31). Despite tests showing that uncontaminated water entering the landfill is polluted when leaving, the defendent is able to forestall any administrative or regulatory attempts by the State to achieve water quality plan objectives in this location. The State has been challenged on how its samples are being taken and not maintaining a good chain of custody among other reasons (See Appendix B).

V-1 Pennsylvania V. Mahon (1922).

V-2 D. Mandelker, The Zoning Dilemma 4 (1971).

V-3 Residual Waste: Model State Legislation, EPA 440/9-76-004. Water Quality Management Guidance. Water Planning Division. U.S. Environmental Protection Agency, Ch. V, (§5.2.7). March 1976.

V-4 D. Hagmen, J. Larson and C. Martin, California Zoning Practice §7.59. (Cal. Cont. Educ. Bar ed. 1969).

V-5 *Barbier* vs. *Connolly*, 113 U.S. 27, 31 (1885).

V-6 362 U.S. 440 (1960).

V-7 See V. Prosser, Torts §§87-92 (3rd ed. 1964).

V-8 Residual Waste: Model State Legislation, EPA 440/9-76-004. Water Quality Management Guidance. Water Planning Division. U.S. Environmental Protection Agency, Ch. IV, (§SVII). March 1976.

V-9 83 Wis. 583, 53 N.W. 912 (1892).

V-10 174 Neb. 234, 117 N.W. 2d 322 (1962).

V-11 200 Cal. App. 2d. 54.

V-12 472 S.W. 2d 714, 3 ERC 1545 (Ark. 1971).

V-13 107 N.H. 131, 218 A. 2d 360 (1966).

V-14 201 Pa. Superior Ct. 614, 193 A. 2d 670 (1963).

V-15 Residual Waste: Model State Legislation, EPA 440/9-76-004. Water Quality Management Guidance. Water Planning Division, U.S. Environmental Protection Agency. Ch. IV (§X). March 1976.

V-16 354 F. 2d 608 (2d Cir. 1965), cert. denied, 384 U.S. 941 (1966).

V-17 Residual Waste: Model State Legislation, EPA 440/9-76-004. Water Quality Management Guidance. Water Planning Division, U.S. Environmental Protection Agency. Ch. V. March 1976.

V-18 *Larkins* vs. *Kohlmeyer*, 229 Ind. 391, 98 N.E. 2d. 896 (1951).

V-19 291 S.W. 2d 792 (Tex. 1956).

V-20 See *People* vs. *Los Angeles*, 160 Cal. App. 2d 494, 325 p. 2d 639 (Dist. Ct. App. 1958).

V-21 *People* vs. *Cunard White Star. Ltd.*, 180 N.Y. 413, 21 N.W. 2d 489 (1939).

V-22 Residual Waste: Model State Legislation, EPA 440/9-76-004. Water Quality Management Guidance. Water Planning Division. U.S. Environmental Protection Agency. Ch. V (§IVB and §XII). March 1976.

V-23 66 N.J. Super. 334, 169 A. 2d 165.

V-24 15 Mich. App. 657, 167 N.W. 2d 355.

V-25 113 Tenn. 331, 83 S.W. 658 (1904).

V-26 26 N.Y. 2d 219, 257 N.E. 2d 870, 309 N.Y.S. 2d 312, 1 ERC 1175 (1970).

V-27 McCall, J.H., *Utility Concept and Solid Waste Systems* - 4th annual meeting of the Institute for Solid Wastes of the A.P.W.A. September 16, 1964, Cleveland, Ohio.

V-28 Tahoe Regional Planning Compact, PL 91-148, 33 Stat. 360, became law on December 18, 1969.

V-29 Personal communication, A-T-E Management; operator of 28 large city bus systems, Cincinnati, Ohio.

V-30 Minnesota. Session laws. An act relating to the Metropolitan Council; providing for the creation of a sewer service board and prescribing its duties and powers; providing for the collection, treatment and disposal of sewage in the metropolitan area. Chap. 449, S.F. No. 237, 1969. (codified in Minnesota stat. annotated, Chap. 473C. Metropolitan Sewer Service [new]).

V-31 N.J.S.A. 58:10-1, 58:10-23.1 and 23:5-28.

6.0 APPLICATION OF MANAGEMENT PRACTICES

Programs for management of vast quantities of residuals often fall short of their goals, which is providing adequate protection of water quality. Because residual wastes are the end products of all processes, the management of residual wastes clearly cannot be considered separately from the processes and systems that produce the wastes. Just as the environment -- air, water, and land -- must be considered and treated as a continuous whole, residual wastes cannot be successfully compartmented for separate handling. For purposes of discussion in this Handbook we are considering wastes in terms of nine major categories, based on source, e.g., feedlot residuals, combustion residuals, etc. (See Section 2). In developing a management program, however, the planners must work toward total waste management on a State or areawide basis, with emphasis on (1) whenever possible, reducing at the source and recovering resource values contained in residual wastes (Ref. VI-1) and (2) satisfactory, land disposal of any element or fraction of the residual wastes not amenable to economic recovery or utilization.

In this section of the Handbook we consider the planning process in detail, showing how the diverse aspects of a comprehensive residuals management program can be approached in a logical and systematic manner. Planners using this Handbook should take into account information presented in Sections 1 through 5 in approaching actual areawide or State residual waste management problems. The discussion of planning procedures is followed by a case study based on a hypothetical seven-county region in the midwestern United States. A hypothetical case was constructed in order to illustrate the variety of issues that must be faced in areawide or State residual waste planning in the future and because an actual model does not exist. The Section is not intended as an exhaustive treatment of residual waste management as applied since these aspects were covered in detail in the previous five sections. The case study illustrates both the planning process and the application of specific management practices to develop a total residuals management system as part of water quality management planning. Many of the considerations, approaches, and techniques presented earlier in this Handbook are applied in the case study. The planning approach, data gathering, and analyses described in the following sections was emulated in the case study and may be useful to the users of this Handbook to understand the mechanisms.

6.1 THE PLANNING PROCESS

Planning is a conscious process for achieving proposed objectives. In this process any likely contingencies and alternatives are considered rationally and fully. Implementation and the means for achieving it must be kept in mind by the planner throughout the planning process.

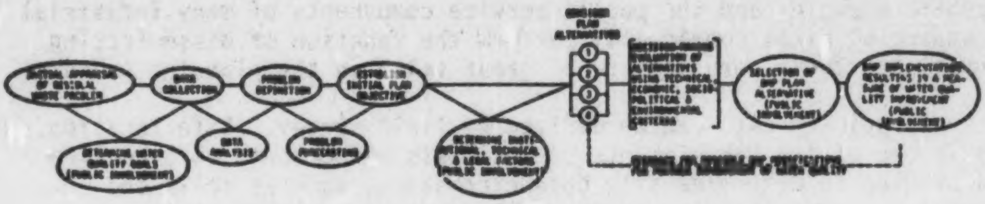

INITIAL APPRAISAL OF RESIDUAL WASTE PROBLEM
DATA COLLECTION
PROBLEM DEFINITION
ESTABLISH INITIAL PLAN OBJECTIVE
DETERMINE WATER QUALITY GOALS (PUBLIC INVOLVEMENT)
DATA ANALYSIS
PROBLEM FORECASTING
DETERMINE INSTITUTIONAL, TECHNICAL & LEGAL FACTORS (PUBLIC INVOLVEMENT)
DESIGN PLAN ALTERNATIVES
1
2
3
4
DECISION-MAKING EVALUATION OF ALTERNATIVES USING TECHNICAL, ECONOMIC, SOCIO-POLITICAL & ENVIRONMENTAL CRITERIA
SELECTION OF BMP PLAN ALTERNATIVE (PUBLIC INVOLVEMENT)
BMP IMPLEMENTATION RESULTING IN A MEASURE OF WATER QUALITY IMPROVEMENT (PUBLIC INVOLVEMENT)

Figure 6-1. The Planning Process.

Planning is a systematic process that is dynamic rather than fixed (Ref. VI-2). Implementation and planning may even occur concurrently with the process allowing for feedback and adjustment. Figure 6-1 illustrates the planning process as applied to residuals management. The objective is the protection and improvement of water quality. Activities and strategies involved in application of management practices to residual wastes are conducted within a given time frame, and an order of priorities is established. The first step is to gather the basic information required for problem assessment. Amount and detail of data will be determined by the extent of the problem.

Information required for planning may include the current residual disposal practices, current and projected populations in the study area, current and projected land use, costs and other economic factors, existing and potential institutional arrangements, transportation facilities, and pertinent laws and regulations. Additional information essential to proper planning and implementation of residual waste management plans include often overlooked public preferences. Failure to take public preferences into account may prevent an otherwise feasible plan from being implemented. Financing and operating residual waste management programs will fall most directly upon individuals, firms, and local and State government. Early measures to solicit information from these individuals and organizations should be taken in the planning process. Usually citizen advisory groups broadly representing those most affected will provide one forum for developing planning information and data. At pivotal points in the planning process, the general public should be informed and consulted.

6.2 BASE STUDIES

Basic to the planning study is detailed information on residual waste generation in the study area. Planners must know the residual waste sources, characteristics of the waste materials, and the quantities that are generated under various circumstances. These are primary data. Other data may be obtained from secondary sources, such as local, regional, and State planning agencies; agricultural extension offices; State and Federal soils and geological survey agencies; health and environmental agencies; consulting firms, libraries, and universities.

The public agencies and the public service components of many industrial and commercial firms continually perform the function of disseminating information. Their services are of great value in the planning process.

Additional primary data can be derived by field survey. Site location, which is one of the key elements of residuals management, will require field studies to determine site characteristics, such as soils and hydrogeology. Data related to the full range of environmental concerns can be obtained both in the field and from the secondary sources mentioned above.

6.3 ENVIRONMENTAL ANALYSIS

Environmental analysis is a key element of the residuals waste management program. The total program is environment-oriented, with emphasis on water quality. Again, however, the planner must consider all aspects of the environment that might be affected by the disposal practices proposed. Table 6-1 lists environmental concerns to be considered in planning and applying residuals management practices. The planner need address only those concerns likely to be affected by implementation of a specific management practice. The principle task of an environmental analysis is to predict responses of the environment to specific activities. Table 6-2 presents a guide by which to assess and analyze the potential impacts of a residuals management program.

In order that the environmental analysis may fully reflect emerging management and preferred BMP's, it must be conducted concurrently with the planning of the proposed project. Figure 6-2 depicts the typical phases in preparation of an environmental analysis.

Table 6-1 lists some concerns that should be considered in the environmental analysis.

The analysis must be thorough. It should identify potential positive as well as negative effects. In addition, it should characterize potential impacts as short- and long term, reversible and irreversible, and primary and secondary.

6.4 ORGANIZATION

Implementation of systems for residual waste management depends largely upon public involvement and preferences and the institutional arrangements and operating management (see Section 5.2). Day-to-day implementation of BMP's requires an efficient and effective organization. Six points are crucial in developing an organization for residual waste management: 1) it should be designed to achieve planned objectives; 2) it should have concomitant authority and responsibility; 3) it should fit, both legally and logically, into the overall jurisdiction of which

Table 6-1. ITEMS AND PARAMETER OF ITEMS TO BE CONSIDERED IN ENVIRONMENTAL ANALYSIS

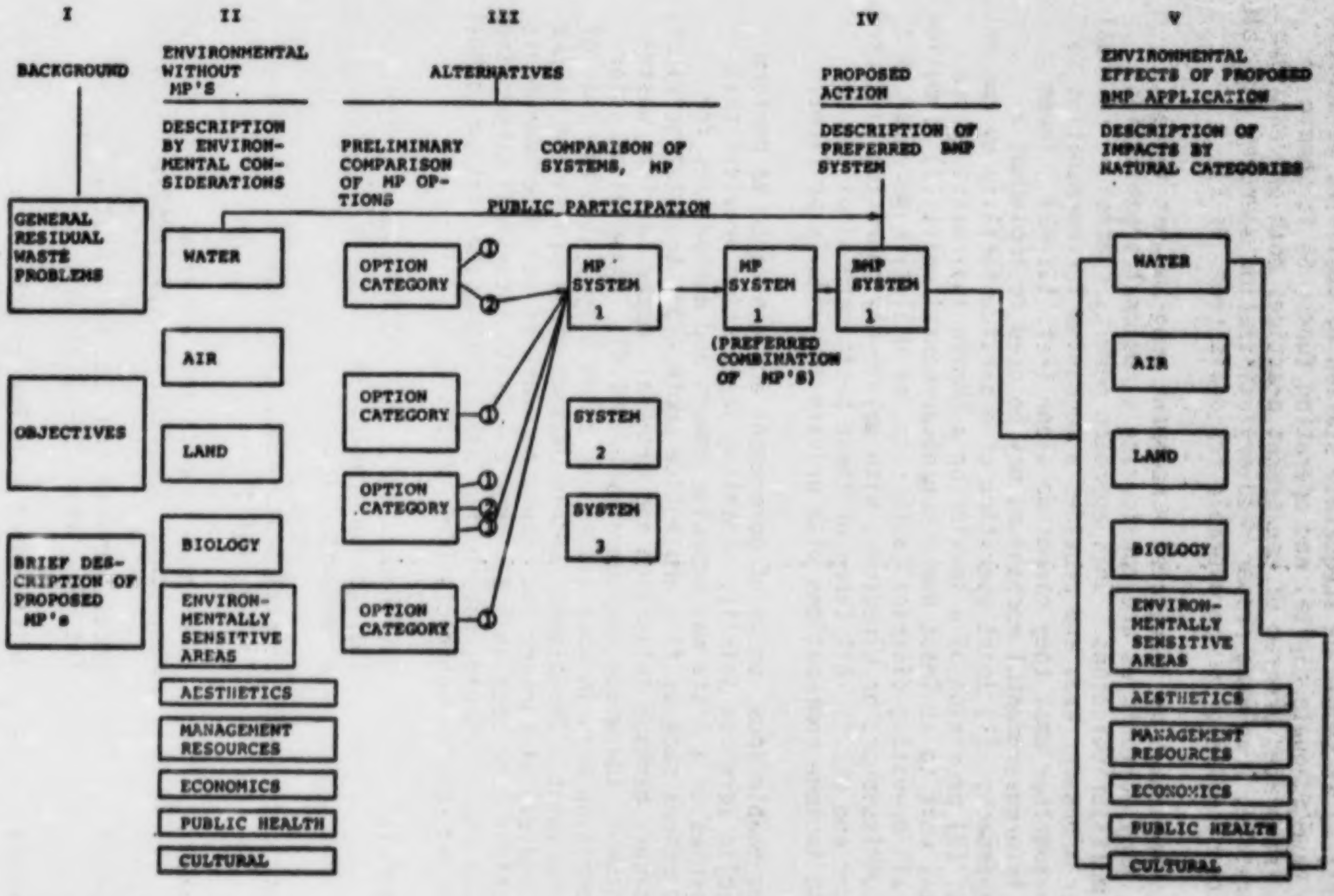
Item subitem	Parameters to be included in description
1. Climate	temperature, precipitation, humidity, wind directions and velocities and frequency of inversions, fog, tornados and hurricanes.
2. Topography	major and minor drainage basins, slope, elevation, erosion and deposition.
3. Geology	geologic structures or formations, area susceptible to earthquakes, landslides, or subsistance, effects on ground and surface waters.
4. Soils	soil types, permeability, erosion potential, expansion and compaction.
5. Hydrology a) General	surface water bodies and groundwater aquifers
b) Water quality	physical, chemical, and biological quality of existing surface and groundwater quality.
c) Water quantity	Surface water volume, flow rates, seasonal variations, groundwater storage volume, rate of recharge and/or depletion of aquifers, structures influencing stream-flow such as dams, locks, tunnels and canals.
d) Water quality and quantity problems	relevant point and non-point sources of pollution (i.e. industry, municipalities, combined sewers, storm water run-off, agriculture, silviculture, mine drainage, salt water intrusion)
e) Water Uses	type and extent of existing and future surface and groundwater use (i.e. recreation, industry, domestic, agriculture).
f) Water quality management	areawide or basin water quality management plans, permits or orders on specific water resources.
g) Flood hazards	25, 50, and 100 - year flood, identify any Corps of Engineers flood-plain plan/plans or proposed project.
6. Biology	designated rare and endangered (state level or nationally). Wildlife habitate or portions thereof to be affected.
7. Air Quality	factors affecting air quality, present and anticipated future air quality in the project area
8. Land Uses	present and projected land use maps, include residential and commercial services, industrial, cluster housing, strip development, transportation routes, open space, recreation, agriculture, water, and other points of interest. Regulatory land use controls not in effect. Development trends in the area. Any aspects which are or will cause environmental impact.
9) Significant environmentally sensitive areas	Using a map show, identify, and describe any sensitive areas which may be significantly impacted by the proposed action
10) Population projections and economic forecasts	5, 10, and 20 year projections, rates of growth. Also using such reports from Dept. of Commerce and the Economic Research Service, Department of Agriculture or Water Resources Council by the Bureau of Economics.
11) Other programs in the area	local, state, or federal projects, planned, a underway which may impact on the area or the proposed project.
12) Aesthetics	the area's general aesthetic quality, noise levels, man-made objects, etc.

Source: Ref. IV-3

Table 6-2. GUIDES HELPFUL IN ENVIRONMENTAL ANALYSIS

A) IDENTIFICATION OF IMPACT	
1. Comprehensiveness	consider full range of probable impacts as derived from Table 1.
2. Specificity	identify specific parameters to be examined
3. Isolate project impacts	identify project impacts as distinct from future environmental changes resulting from other causes.
4. Timing and duration	identify time and duration of impacts
5. Data source	identify sources of data used to identify impacts.
B) IMPACT PREDICTION AND MEASUREMENT	
1. Explicit indicators	indicators used to quantify impact on parameters
2. Magnitude	measurement of impact magnitude as distinct from impact significance
3. Objectivity	emphasize objective rather than subjective impact measurements
4. Predictive tools	what tools are used to predict impact
C) IMPACT INTERPRETATION	
1. Significance	explicit assessment of the significance of measured impacts on a local, regional, and if need be, national scale
2. Explicit criteria	state criteria and assumptions used to determine impact significance
3. Uncertainty	assessment of the uncertainty or degree of confidence in impact projection made
4. Risk	identify impacts of low probability but high damage or loss potential
5. Alternative comparison	compare alternatives as well as no-project alternative
D) IMPACT COMMUNICATION	
1. Affected parties	linking impacts to the specific affected geographical or social groups
2. Setting description	a description of the project setting to aid statement users in developing an adequate overall perspective
3. Summary	present results in summary form
4. Key issues	highlight key issues and impacts identified in the report
5. NEPA compliance	summarize results in terms of the specific points required by NEPA and subsequent CEQ guidelines
6. Aggregation	when and if possible aggregate impacts into a new total (this is usually not practible)
7. Public involvement	public involvement in the interpretation of impact significance

Source: Ref. VI-4


I
BACKGROUND
GENERAL RESIDUAL WASTE PROBLEMS
OBJECTIVES
BRIEF DESCRIPTION OF PROPOSED MP's
II
ENVIRONMENTAL WITHOUT MP'S
DESCRIPTION BY ENVIRONMENTAL CONSIDERATIONS
WATER
AIR
LAND
BIOLOGY
ENVIRONMENTALLY SENSITIVE AREAS
AESTHETICS
MANAGEMENT RESOURCES
ECONOMICS
PUBLIC HEALTH
CULTURAL
III
ALTERNATIVES
PRELIMINARY COMPARISON OF MP OPTIONS
COMPARISON OF SYSTEMS, MP
PUBLIC PARTICIPATION
OPTION CATEGORY
OPTION CATEGORY
OPTION CATEGORY
OPTION CATEGORY
①
②
①
①
②
③
①
MP SYSTEM 1
SYSTEM 2
SYSTEM 3
MP SYSTEM 1
(PREFERRED COMBINATION OF MP'S)
IV
PROPOSED ACTION
DESCRIPTION OF PREFERRED BMP SYSTEM
BMP SYSTEM 1
V
ENVIRONMENTAL EFFECTS OF PROPOSED BMP APPLICATION
DESCRIPTION OF IMPACTS BY NATURAL CATEGORIES
WATER
AIR
LAND
BIOLOGY
ENVIRONMENTALLY SENSITIVE AREAS
AESTHETICS
MANAGEMENT RESOURCES
ECONOMICS
PUBLIC HEALTH
CULTURAL

Source: Ref. VI-5.

Figure 6-2. Environmental analysis flow.

it is a part; 4) it should be adequately staffed by qualified personnel; 5) it must have adequate capital and operating funds; 6) it should conduct an integrated program of management practices both preventative and ameliorative, involving proper recovery/utilization wherever possible and ultimate disposal of nonrecoverable residuals (ref. VI-2).

In order to implement an integrated management program that is cost effective, many communities are considering a regional organization involving multijurisdictions. This approach permits control of residual wastes over a broader area and provides a mechanism for communities to accomplish together what they cannot do alone (Ref. III-42). Three principal intergovernmental mechanisms may be used to implement a regional approach: (1) joint operation of a service facility by two or more units; (2) provision of a service on a contractual basis by one governmental unit to at least one other governmental unit; (3) formation of an overall operating district, authority, or utility supervised by a board of commissioners or directors, with day-to-day operation delegated to a manager and staff. All three of these basic mechanisms can be modified to include combinations with private individuals or firms.

Many States enable local units of government and districts to perform various public services jointly. Enabling legislation provides that public agencies of a State may exercise powers and authorities for sharing functions such as fire and police protection, hospital services, communications, garbage collection and disposal, water service, wastewater treatment, and waste management (Ref. VI-6). Examples of interlocal cooperation acts in some states are cited below, with the year of original enactment. The planner should examine these provisions in the State (or States) of concern and should be aware of possible amendments and limitations (See Section 5.2). Not all State interlocal cooperation statutes are equally broad, nor do they all extend authorization to both agreements and service contracts (Ref. VI-7).

California - Government Code, Sec. 51300-51335, (service contracts, Sec. 6500-6578 agreements) (1921).

Connecticut - General Stat. Ann., Sec. 7339a to 7339 1 (1961).

Indiana - Interlocal Cooperation Act, Ind. Ann. Stat., Sec. 53: 1101-07 (1957).

Louisiana - Local Services Law, La. Rev. Stat., Tit. 33, Sec. 1321-32 (1942).

Minnesota - Joint Exercise of Powers Act, Minn. Stat. Ann., Sec. 471.59 (1943).

North Carolina - General Stat., Sec. 153-246 (1933).

Ohio - Joint Municipal Improvement Act, Ohio Rev. Code Tit. 7, Sec. 715-02 (1965).

Virginia - Virginia Code Ann. Sec. 15.1-21 (1958).

6.5 FINANCING

Early in program development, planners must address the financing of any plan for residual waste management. Without an accurate assessment of capital requirements and operating and maintenance (O&M) costs for a BMP approach, implementation may be delayed or prevented. While the typical State or areawide water quality planning agency will not implement a residual waste management activity in the operational sense, it is encumbant upon planners to provide estimated costs for implementing plans. Implementing agencies, firms, or individuals have two basic sources from which to obtain capital for facilities and equipment: borrowed funds and current revenues. A third alternative for public agencies is to contract with private firms to manage residual wastes and shift the burden of capital-raising onto them (Ref. III-42). An agency cannot, however, escape paying the cost of such capital because costs will be reflected in the service charges they must pay. Sometimes public agencies may use State or Federal grant funds effectively.

6.5.1 Debt Financing

Governmental agencies and private firms utilize several mechanisms for securing funds through borrowing. Bonds, bank and insurance company loans, and leasing are common sources of funds. Governmental agencies typically utilize general obligation (GO) bonds and revenue bonds in generating funds for capital expansion. GO bonds are usually less costly in terms of total costs of issuance and servicing. GO bonds are secured through the full faith and credit of the agency and its ability to retire the bonds through tax levies on real estate in its jurisdiction. A major disadvantage is that many States limit GO debt as a ratio of total GO debt outstanding to assessed valuation of real property. As a practical matter sufficient GO bond capacity may not be available for funding residual waste management because the agency may already be using its debt capacity for schools, streets, water supply, and other public services. Revenue bonds, on the other hand, are not usually limited in this way. Municipal revenue bonds, however, are usually more costly to issue and service than either GO or industrial revenue bonds. In addition, all revenue bonds must be self-liquidating through income generated by the system facilities. Industrial revenue bonds issued by a governmental agency on behalf of a private organization serving the agency are usually less costly. Nearly all states allow this form of debt.

Cost of bond debt involves the various issuing costs, such as legal fees, underwriting, printing, and possible public referendum (for GO bonds) in addition to interest that must be paid. Interest rates vary widely; the current interest depending partially on the rating of the agency issuing the bonds. Two statistical organizations, Moody's and Standard and Poor's, have been accorded official recognition for rating. The ratings designate the likelihood of prompt payment of interest and safety of principal over a term of years. Moody's Investor Service provides nine ratings running from the highest, Aaa down to the lowest, C. Standard and Poor's gives eleven ratings, from AAA down to D.

Bank loans can be useful for short-term financing and for stabilizing the cash flow of a residual waste management system. Long-term borrowing is usually better facilitated through bond issuance. Likewise, leasing, which is not technically borrowing, offers some of the same advantages and disadvantages. Facilities and equipment needed immediately are obtained by delayed payment through spreading over time. Also, interest is an integral part of the lease payment. Leasing arrangements are often more advantageous to small companies since no substantial cash outlay is required initially. In addition, because lease charges are treated as an expense, companies may reduce taxes by reducing the taxable income.

6.5.2 Current Financing

Often termed 'pay-as-you-go' financing, capital equipment and facilities are purchased as needed. Although such financing has a ring of prudence it is often unsatisfactory for large expenditures. Large amounts of capital may be needed and may not be available from annual public revenues or surplus funds. Current financing may be more appropriate for covering O&M costs than for capitalization.

6.5.3 Grant Funds

Because availability of grant funds depends on governmental programs, policies, and supplies of funds, grants are not considered in long-term financing plans of agencies that need immediate facilities. Nevertheless, coincidence of needed facilities and availability of State or Federal grant funds may result in a fortuitous match. For example, a source of funding to provide land for land spreading is authorized under the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) according to a Decision Memorandum issued by the EPA Administrator in late 1975. Federal funds not to exceed 75 percent of land costs may be available for eligible projects that are considered cost-effective. The cost-effectiveness test must precede the Federal funding and cannot depend on it. Funds can be used for land purchase, but not for land preparation, access roads, buildings, equipment, operations, and the like. Grant funding has potential for regional application in a joint operating approach as well as for single plant systems. However, the cost-effectiveness test may be more easily met through a regional approach (Ref. VI-6). Regional approaches offer elimination of duplicate services and staffs, provide uniform centralized management, and lowered unit costs and other economies of scale. Residual waste management and planning scenarios contained in the following case study will acquaint the planner with the technique of applying BMP's in a hypothetical, but realistic situations.

6.6 CASE STUDY[a]

The Central Region Organization of Governments (CROG) was formed for the purpose of improving certain functions that are common to the seven participating counties, but cannot be handled efficiently by any county alone. The organization had begun in the early 1960's with informal meetings of certain civic leaders who saw the potential benefits to be derived from unified effort. As the concept became better defined, two attorneys of the group researched the State codes to determine the provisions of enabling legislation (See Section 5.1). Formation of CROG resulted from many months of effort on the part of county officials and representatives of the major municipalities. Although the initial need was primarily for planning development of regionwide support services, such as transportation, the organization now handles multiple regional functions.

The institutional mechanism for a regional planning approach to residuals management was available within the framework of CROG. What was lacking, however, was an organization under CROG jurisdiction whose specific function is to develop and administer the residuals management program. As CROG officials reviewed the six criteria (Section 6.4) applicable to such an organization, they found that the existing CROG structure provided for the required concomitant authority and responsibility to plan and it also ensured that the residuals program would be logically tailored to the CROG jurisdiction. Of the remaining organizational criteria beyond the control of CROG, the two principal requirements involved staffing and funding. Because CROG is not an operating agency with the authority to manage residual wastes as recommended in its plans, implementation is dependent upon others (See Section 5.2). Implementing operations are typically conducted by agencies, such as sewer districts, individuals and firms, and State government enforcing adequate regulations. The problem of implementation became readily apparent to CROG's Citizen Advisory Committee (CAC). The CAC was established to provide public participation in the areawide water quality planning program under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The CAC therefore passed a resolution to form a law review committee (LRC) to determine legal and institutional mechanisms available to implement CROG's residual waste management plan. The LRC was expected to review the statutes for enabling authority, examine existing authority and mechanisms being exercised, and to determine new legislative authority or regulations required. The CAC asked the LRC to report back its findings and recommendations within six weeks as part of the planning program base study phase. Later CAC expected to relay these findings and its recommendations to the CROG Board of Commissioners to help guide implementation of the areawide water quality plan. Meanwhile, the CROG areawide water quality planning base studies proceeded with collection of the other data needed for planning.

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[a] This case study is hypothetical using fictitious data and other facts. Nevertheless, the planner is provided a realistic demonstration of fundamental steps and considerations inherent in residual waste management planning.

Base Studies of CROG

Data gathering for base studies of the CROG area relied heavily upon information provided by public agencies. Population and employment data were obtained from city and county records, including registrations, permits, and assessments. As in most areas, population and employment data are summarized routinely for use by local promotional groups, chambers of commerce, businessmens' clubs, and similar organizations. Land use information was assembled by county; information pertaining to agricultural land use was verified and augmented by records of the U.S. Department of Agriculture, Soil Conservation Service.

By arrangement with the Department of Environmental Sciences, Midland University, a cooperative program was established whereby graduate students could participate in field surveys and data analysis as part of postgraduate programs. The students worked primarily on technical and scientific aspects of the base studies, assuming responsibility for basic descriptions of the biology, topography, hydrogeology, and climatology of the CROG area. In this work they obtained information from local offices of the U.S. Geological Survey, the Agricultural Extension Service, U.S. Weather Service, and other local representatives of Federal agencies. The students participated in field surveys and contributed to the data base required for evaluation of potential sites for landfill, land spreading, and lagooning. Further, they assisted in the full-scale environmental assessment, which was performed for CROG by contract with an environmental consulting firm.

It will be noted that the information generated in the base studies constitutes much of what is required for the environmental assessment. These data provide the base from which to estimate the environmental impacts of proposed residuals management practices. Results of base studies of the CROG area are summarized in the following paragraphs. Residuals management practices, both current and proposed, are then discussed in detail with respect to each of the major residuals categories.

The CROG Region

The seven counties comprising CROG cover an area of approximately 3200 square miles. Figure 6-3 depicts the CROG area, showing locations of the seven counties. The most urbanized portions of the area are Jefferson, Lee, and Davis Counties and the southwest portion of Adams County. Several of the urban centers, particularly Main City, are heavily industrialized. Some suburban development is occuring in Washington County. Quincy and Madison Counties remain largely rural, with considerable agricultural activity including the raising of crops and confined feeding of livestock.

Population

Projections prepared by CROG indicate that by the year 1995, population of the seven-county region will reach 2,934,000, which is twice the 1975 population, as shown in Table 6-3. About half of the current population resides in Jefferson County. This proportion is expected to decline by 1995 as other CROG counties urbanize.

This projected growth will present challenges to preservation of the region's environmental quality. The impacts of residual wastes will increase, since many residuals are directly related to population. At the local level, the categories most directly a function of population are wastewater sludge, septage, water treatment residuals, and municipal refuse. On a national basis, population secondarily relates to feedlot waste generation, since the number of animals confined in feedlots is a function of meat consumption. In addition, quantitative inferences may be drawn for residuals from combustion and industrial sources as a function of employment, although the relationship may be indirect. For example, certain highly automated industries do not require large numbers of employees but may generate large amounts of residual wastes during processing.

Employment

The CROG region has grown and prospered as a result of its advantageous location. Impetus to growth has come from processing industries, commercial enterprises, agricultural product processing, and rapid mechanization of farming operations including the feeding of beef cattle and hogs. Employment is expected to grow steadily to 1995, as shown in Table 6-4.

Physical Characteristics

Topographic features range from a minimum elevation of 690 feet Mean Sea Level (MSL) along the Green River flood plain in Jefferson County to a maximum elevation of 1160 feet MSL in northeastern Quincy County. The greatest variations in topography occur adjacent to the flood plains of the Green and Central Rivers.

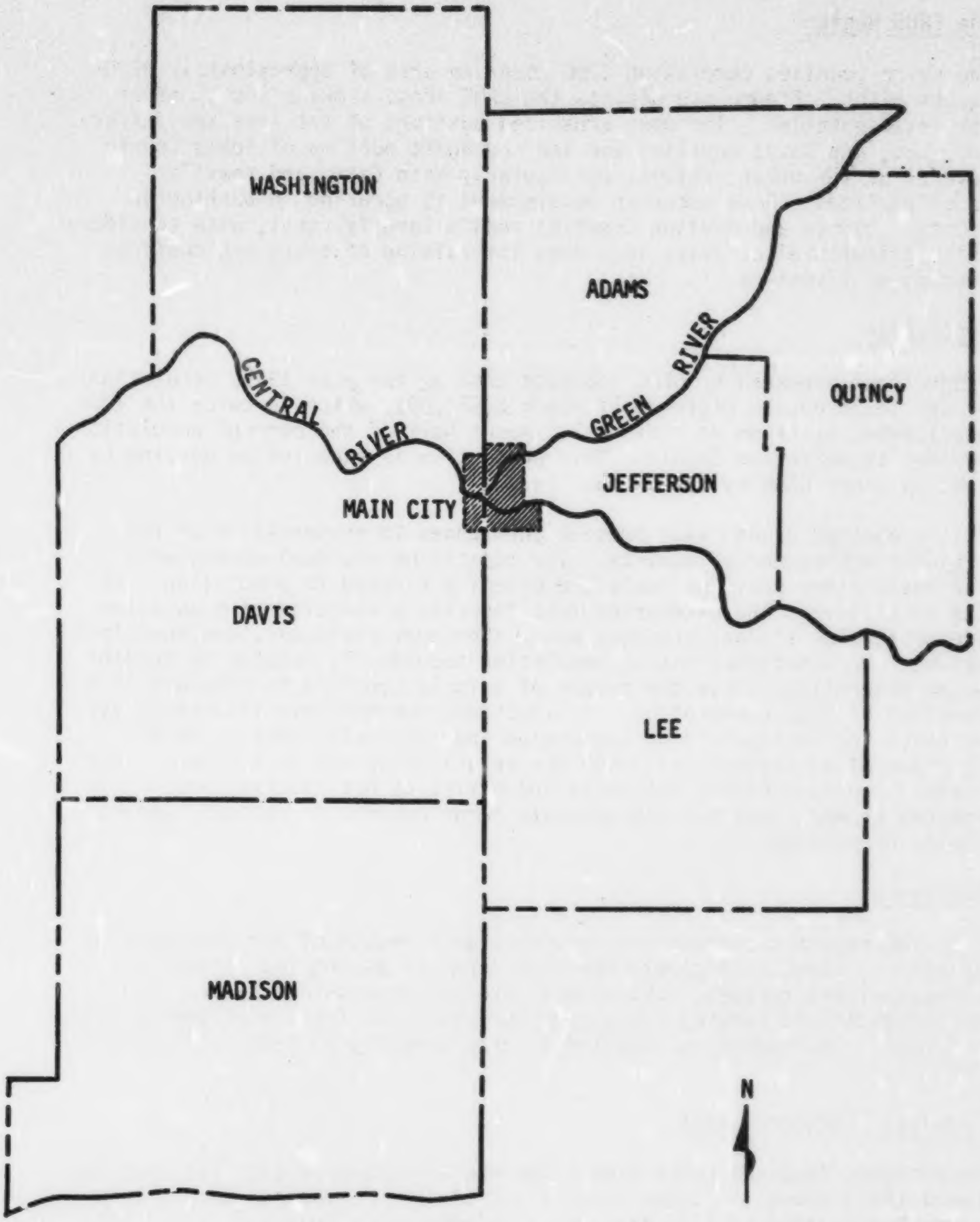
WASHINGTON
ADAMS
QUINCY
CENTRAL RIVER
GREEN RIVER
JEFFERSON
MAIN CITY
DAVIS
LEE
MADISON
N

Figure 6-3. Central Region Organization of Governments Seven County Area (CROG).

Table 6-3. SUMMARY OF EXISTING AND PROJECTED POPULATION

County	1975 Urban	1975 Rural	1975 Total	1995 Urban	1995 Rural	1995 Total
Adams	113,264	28,736	142,000	275,017	94,983	370,000
Davis	204,233	8,767	213,00	313,500	16,500	330,000
Jefferson	726,397	17,603	744,000	1,174,424	75,576	1,250,000
Lee	216,853	19,147	236,000	588,036	41,964	630,000
Madison	15,314	26,686	42,000	56,529	43,471	100,000
Quincy	24,143	13,857	38,000	68,083	90,917	159,000
Washington	38,525	17,475	56,000	63,332	31,668	95,000
Region	1,338,729	132,271	1,471,000	2,538,921	395,079	2,934,000

Table 6-4. SUMMARY OF EXISTING AND PROJECTED EMPLOYMENT
(Numbers of Employees)

County	1975 Manufacturing	1975 Non-manufacturing	1975 Total	1995 Manufacturing	1995 Non-manufacturing	1995 Total
Adams	12,157	30,308	42,465	18,500	77,800	96,300
Davis	24,267	58,404	82,671	36,200	119,400	155,600
Jefferson	89,226	297,033	386,259	128,735	474,665	603,400
Lee	8,856	43,241	52,097	20,865	123,635	144,500
Madison	1,012	9,874	10,886	4,100	18,700	22,800
Quincy	271	11,621	11,892	18,500	67,500	86,000
Washington	1,595	11,531	13,126	3,500	17,100	20,600
Region	137,384	462,012	599,396	230,400	898,800	1,129,200

Consolidated rocks occur at shallow depths throughout most of the region. The rocks are primarily low-permeability shales, sandstones, and limestone. The quantity of cover material available for sanitary landfills is limited. In addition, the potential for ground water contamination is high. The presence of bedrock at shallow depths creates an additional problem because it impedes downward flow of ground water. At some sites it may be impossible to maintain an adequate aerobic zone, and problems will occur if liquid loading rates are high. Loess, alluvium, and glacial drift are present in some locations in quantities adequate to provide cover material or to receive spreading of residuals. Areas in which the drift consists of thick till may be suitable for landfill sites. The major loess deposits occur along the main river valleys. In Jefferson County deposits in the bluffs adjacent to the Green River reach a maximum depth of over 100 feet. Alluvial deposits occur along the creek and river valleys. Depth of alluvium exceeds 100 feet in parts of the Green River valley; in much of the Central River valley it exceeds 50 feet. Ground water from the alluvium is a major source of industrial water and serves as a supplemental public water supply. Glacial drift deposited by the Central and Green glaciers overlies bedrock in a large part of CROG. The southern limits of glacial deposits extend to Davis, Lee and Madison Counties and in some places a few miles south into those counties (See Section 4).

Climate

The climate of CROG is marked by seasonal variations in temperature and precipitation. The average annual temperature is 51.1 F. Average daytime temperatures in midsummer range from 85 to 87 F. Average daytime temperatures in winter range from 31 to 32 F, nighttime winter temperatures average from 15 to 19 F. Humidity ranges from 55 to 60 percent from noon to midnight, and 75 percent to 80 percent from midnight to noon. The average annual precipitation is 28.63 inches, 75 percent of which falls between April and September. The average normal snowfall is 28.50 inches. Northwest winds predominate in winter months, and south and southeast winds in summer.

Land Use

Table 6-5 indicates major land uses for each CROG county. Jefferson County is almost completely developed for urban use and presents little possibility for land disposal of residual wastes. Although Adams, Davis, and Lee Counties are urbanizing, suitable land disposal sites may be available in outlying areas. Indeed, because of the rapidly urbanizing trends in these CROG counties, land sites must be sought and selected soon to accommodate the growing generation of residuals. Both Quincy and Madison Counties are growing relatively slowly and will remain agricultural for the foreseeable future. Washington County will grow slowly in outlying areas and remain largely agricultural. Population will continue to be concentrated in the Main City area.

Table 6-5. EXISTING AND FUTURE LAND USES, PERCENT BY MAJOR USE

	Urban		Urbanizing		Non-urban	
County	1975	1995	1975	1995	1975	1995
Adams	20.0	26.5	6.5	6.0	73.5	67.5
Davis	22.5	29.0	6.5	6.0	71.0	65.0
Jefferson	71.5	79.0	7.5	3.5	21.0	17.5
Lee	25.0	31.0	6.0	5.5	69.0	63.5
Madison	8.0	8.5	0.5	0.5	91.5	91.0
Quincy	9.5	10.0	0.5	0.5	90.5	89.5
Washington	11.0	14.5	3.5	3.0	85.5	82.5

Legal/Institutional

As contended earlier by the CAC, the LRC determined through its studies that implementation of the residual waste management plan will indeed depend upon agencies and authorities lying largely outside the control of CROG. Nevertheless, the LRC reported its findings to CAC emphasizing that CROG could influence implementation of its plan through various approaches. The LRC examined legal and institutional mechanisms for nine predominent residuals (See Section 2). Basically, the LRC found that management and disposal of sludges from wastewater and water treatment plants and septage could be accomplished through the various sewer districts in CROG. Employing interlocal or joint service agreements sewer districts could accomplish centralized sludge disposal cost-effectively while maintaining water quality (Ref. VI-7). The LRC determined that this approach may be possible in many States although not presently widely practiced (See Section 5). Likewise, the LRC recommended that municipal refuse be similarly managed to provide economies of scale. Private contractors, public crews, or a combination arrangement may be employed. The LRC was basically satisfied that water quality would be protected from disposal of municipal refuse. State sanitary landfill regulations are rigorously enforced by State EPA district officers. Strict design and review standards requiring lining to impede percolation of leachates into ground water or diversion of leachates to treatment control lagoons are routinely applied throughout the State. State-enforced standards governing industrial wastes and residuals from combustion and air pollution controls require employment of management practices protecting water quality. Because those involved in industrial waste collection and disposal are largely individuals and firms, CROG must rely upon State EPA enforcement to maintain standards. However, future location of disposal areas could be controlled to some extent by CROG through local zoning boards (See Section 5.1.1.3). While zoning is traditionally a local power, CROG could use its persuasion to influence local zoning boards to consider regional interests. This could also affect location of future residential, commercial, and industrial development and, therefore, indirectly affect residuals generation.

The LRC also recommended that county/local zoning boards be approached to develop provisions prohibiting animal feedlots from certain locations, particularly flood plains and other places where water quality may be impaired. It was observed by the LRC that several feedlots are already located on flood plains and that zoning provisions allow nonconforming uses if operating before a zoning prohibition had been enacted. While future feedlots could be prohibited from locating on flood plains or other water quality sensitive areas, how could existing feedlots be removed and relocated? The LRC reviewed a proposed EPA regulation governing discharges from feedlots judged point sources thus requiring a National Pollutant Discharge Elimination System (NPDES) permit (40 CFR 125). While CROG cannot enforce the NPDES provision the LRC recommended to CAC that support be given to EPA in approving this proposed regulation. If promulgated, the regulation would require feedlot operators to either meet discharge standards or relocate. Such a regulation could assist CROG in proposing and implementing its land use plans.

Although mining in CROG is not a large economic activity, its impact upon water quality is potentially significant. The LRC review of mining laws in the State reveal a lack of sufficient protection to water quality through the regulations themselves as well as a lack of diligence in their enforcement. There is evidence that water quality in receiving streams in parts of the State has deteriorated from acid mine drainage, sulfates, and siltation. The LRC considered engaging the mining companies in discussions leading to voluntary water quality control and reclamation. However, LRC decided to recommend a more direct approach as well. It was felt that more fundamental changes were needed in the State Mine Reclamation Act and its enforcement. Therefore, the LRC recommended to CAC that the State legislature be approached to amend the Mine Reclamation Act and to renew budget commitment to its enforcement.

Protection of water quality from dredge waste is dependent upon the U.S. Army Corps of Engineers District for designated waterways in CROG. Sufficient regulatory authority to protect water quality resulting from dredge wastes is apparently available. Actual management of dredge waste deposited upon the land does not always conform to provisions, however. The LRC decided to recommend to CAC that the district office of the Corps of Engineers be invited to place a member upon the CAC conservation sub-committee so that CROG plans can be conveyed into action through management practice by the Corps of Engineers as well as through its permitting authority (See Section 5.2.2).

Residual Waste Management

As a result of an extensive program of public information, the citizens of CROG are acutely aware of the growing problems of waste disposal and they support the efforts of CROG planners in developing a comprehensive residuals management program. In the following pages the residuals of the CROG area are considered by category, by the CROG staff, with an analysis of current disposal methods and proposals for improved management practices (See Sections 2 and 3).

The BMP's emerging from this analysis by category represent the framework of an integrated residuals management system for the CROG area. Although recognizing that application of these BMP's individually or in combination may not prove totally effective, the CROG planners anticipate sustantial improvement over present practices and significant beneficial impacts on water quality.

6.6.1 Wastewater Sludge

Disposal of wastewater sludge is a growing problem for the CROG area. In the past it has been disposed of by the lowest-cost methods possible, with little regard to the environmental hazards involved (See Section 2.1). With the projected increase in population and the resulting requirement of more advanced wastewater treatment facilities, disposal of sludge will constitute a problem of major proportions.

6.6.1.1 Present and Projected Sludge Quantities for the CROG Area Population - The total quantity of sludge generated in the CROG area is shown in Table 6-6.

Table 6-6. CURRENT AND PROJECTED SLUDGE GENERATION IN THE CROG AREA[a]

Year	Population	Sludge quantity[b]	
1975	1,471,000	2,758	110
1995	2,934,000	6,876	275

[a] Assume that 75% of the population are served by sewer lines in 1975, and 90% in 1995.

[b] Sludge quantities are shown in wet tons per day and dry tons per day. Sludge production is assumed at 0.20 lb/c/d in 1975 and 0.25 lb/c/d in 1995. The quantities listed do not include sludge from industrial wastewater sources. Industrial loadings are known only for a few individual plants but the entire industrial loading for the CROG area is unknown.

6.6.1.2 Wastewater Treatment Plants - The CROG area is served by 140 wastewater treatment facilities ranging in capacity from 0.05 mgd to 100 mgd. The treatment facilties serve approximately 75 percent of the total population. Most of the plants are located in an area encircling Main City, on the banks of the Central River and the Green River. The facilities are capable of providing a minimum of primary treatment. By 1995, however, all the plants should be upgraded to provide a minimum of full secondary treatment (i.e. primary plus secondary) and some must be capable of providing advanced waste treatment for removal of nitrogen, phosphate, and fine suspended solids.

Each of the wastewater treatment facilities in CROG is responsible for handling and disposing of its sludge. At present the plants of less than 1.0 mgd capacity, located in outlying areas some distance from Main City dispose of their sludge by land application. The ten major plants, as shown in Figure 6-4, are equipped with multi-hearth incinerators and dispose of the slurried incinerator ash in on-site disposal ponds. The rest of the plants have either no facilities for sludge processing and disposal or minimal facilities.

6.6.1.3 Alternative Disposal Methods - Plant No. 2 (Figure 6-4) was selected by CROG staff to test alternative BMP's that may be applied elsewhere in the region. It is the largest wastewater treatment plant in CROG, with an average daily flow of 100 mgd. It serves approximately 70 percent residential/commercial population and 30 percent industrial population. The major industries served by the plant include chemical processing, electronics, paper and allied products, food processing, and metal fabrication. Plant No. 2 serves a domestic population of about 700,000.

No pretreatment standards have been promulgated in CROG. Plant No. 2 provides full secondary treatment followed by postchlorination of the effluent. Sludge processing facilities include chemical conditioning using lime and ferric chloride, vacuum filtration, and incineration. On-site disposal ponds are used for ultimate disposal of slurried ash. The ash ponds have a life of about 25 years.

Total daily production of sludge (raw plus secondary) amounts to 2250 wet tons (2043 metric tons), at 2 percent solids. Daily generation of filter cake amounts to 180 wet tons at 25 percent solids. Ash production amounts to 13.5 dry tons (12.3 metric tons), per day.

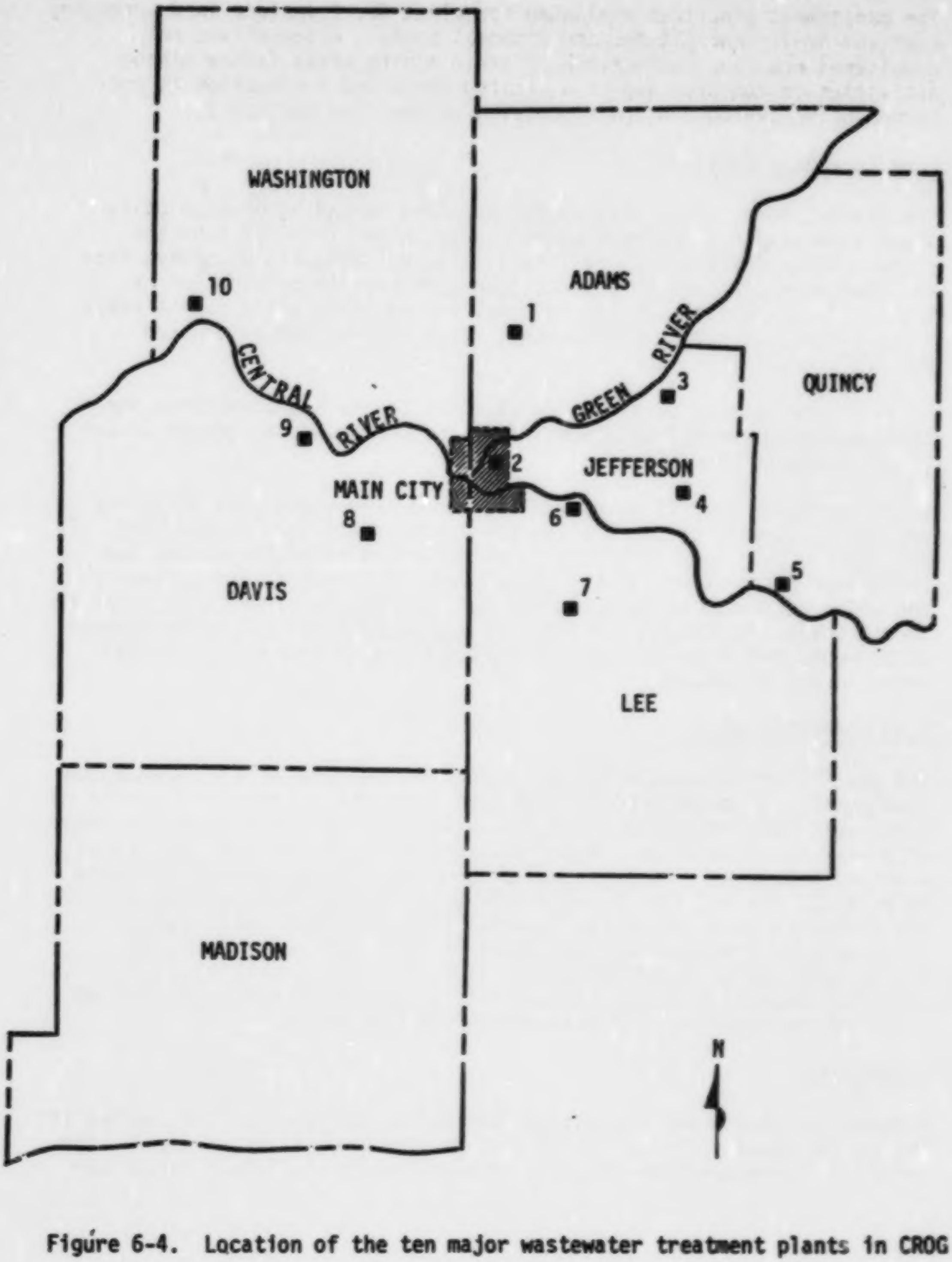
WASHINGTON
ADAMS
QUINCY
JEFFERSON
MAIN CITY
DAVIS
LEE
MADISON
CENTRAL RIVER
GREEN RIVER
1
2
3
4
5
6
7
8
9
10
N

Figure 6-4. Location of the ten major wastewater treatment plants in CROG

The management practices evaluated for plant No. 2 include land spreading (wet and dry), landfilling, and disposal ponds. Alternatives not considered are land reclamation of strip mining areas (since mining activities in the area are on a limited basis and reclamation is preformed using overburden and processing wastes (See Section 3).

Land Spreading (Wet)

The nearest rural area suitable for wet land spreading of chemically stabilized sludge is in Washington County, about 10 miles from the plant. Since there are no rail facilities or navigable waterways from the treatment plant to this area, transport must be by pipeline or truck. Investigations indicated pipeline transport would not be economical because of the long distances, steep slopes, and associated pumping costs.

Soils in the central portion of Washington County are acceptable for land spreading, with little possibility of contaminating ground waters (See Section 4).

Truck transport over 20 miles (32 km) round trip would cost $1.60 per wet ton (1.76/metric ton) for the chemically stabilized sludge (Ref. VI-8). Cost of wet land spreading is estimated to be $1.08 per wet ton (1.19/metric ton) (Ref. VI-8). Total cost of transport and spreading is therefore estimated to be $2.68 per wet ton ($2.95/metric ton), or on an annual basis, $2,200,950. Processing equipment (chemical conditioning unit) would add a capital cost of $380,000 and an operating and maintenance cost of $30,000.

Land Spreading (Dry)

The dry filter cake could be land spread in the same area in Washington County, that is considered for wet land spreading. In order to preserve local water quality contour plowing as well as dikes and detention ponds will have to be utilized. Again trucking would be the most economical means of transport. Cost of transporting the filter cake is estimated to be $1.07 per wet ton ($1.18/metric ton) (Ref. VI-9). Spreading costs are estimated at $1.00 per wet ton ($1.10/metric ton) (Ref. VI-10). Total cost of transport and spreading is $2.07 per wet ton ($2.28/metric ton), or on an annual basis, $135,999. Processing equipment (chemical conditioners and vacuum filters) would add a capital cost of $830,000 and operating and maintenance cost of $57,000.

Landfilling

A major, privately owned sanitary landfill is situated within 5 miles (8 km) of the plant. The estimated life of the landfill is 20 years. The landfill is now used for disposal of solid waste (household refuse and garbage), but could accomodate a mixture of solid waste and dewatered sludge. The addition of sludge to the landfill, however, may pose a greater threat to local water quality. Liners of any type are not presently utilized in the landfill. The addition of dewatered sludge (25% solids) to the landfill would greatly add to the potential of leaching into the ground water because of the increase in moisture content of material being landfilled. Therefore in order to prevent degredation of ground water the landfill would require a clay liner as well as proper excavation to divert runoff over the filled areas. The use of a leachate retention pond is also recommended as well as monitoring wells to detect possible leaching into ground water. Transportation by truck to the landfill site is estimated to cost $0.85 per wet ton ($0.94/metric ton), (Ref. VI-8). The average cost of landfilling is estimated to be $4.91 per wet ton ($5.40/metric ton) (Ref. VI-11). Therefore, the total cost of transport and landfilling would be $5.76 per wet ton ($6.34/metric ton), or $378,432 annually. Processing equipment (chemical conditioning and vacuum filtration) would add a capital cost of $830,000 and an operating and maintenance cost of $57,000.

Disposal Ponds

The plant currently disposes of its slurried ash on-site. However, the ground water monitoring program has shown some degradation in ground water quality, particularly an increase in alkalinity in the immediate area of the disposal pond. The disposal pond is unlined. The lining of the pond with clay would in all likelihood prevent further leaching into ground water and contribute to recovery of ground water quality. Cost of clay lining is estimated at $6,000. The average cost of ash ponding is estimated to be $0.32 per wet ton ($0.35/metric ton) (Ref. VI-8). Transport cost (piping) is estimated at $0.03 per wet ton ($0.03/metric ton). Total cost of transport and ponding would thus be $0.35 per wet ton ($0.38/metric ton), or $122,640 annually. Processing equipment (chemical conditioning, vacuum filtration and incineration) would add a capital cost of $2,530,000 and an operating and maintenance cost of $1,110,000.

From a cost-effectiveness standpoint, the CROG staff determined that dry land spreading is the BMP for sludge disposal. It is also the only method by which some soil beneficiation may be achieved. At the same time it will be imperative that the areas where spreading takes place be monitored to detect any dangerous levels of heavy metals or other toxic elements (See Appendix A). Even in properly operated disposal methods, the possibility for ground water contamination exists (See Section 4). For purposes of public presentation and consideration, the CROG staff prepared information regarding cost and ground water factors for regarding each sludge disposal alternative. This information is presented in Table 6-7. CROG planners will present this technical information in preparation for determining legal, institutional, and public acceptability.

Table 6-7. EFFECTS OF WASTEWATER SLUDGES ON COST AND GROUND WATER QUALITY FROM VARIOUS DISPOSAL PRACTICES

COSTS

Residual	Unit Process	Annual Capital Cost ($1,000)	Annual O and M Cost ($1,000)	Total Annual Cost ($1,000)
	Landspreading (Wet)			
Wastewater sludge	Transport & spread		2,201.0	2,201.0
	chemical conditioning	380.0	30.0	410.0
Total cost of alternative		380.0	2,231.0	2,611.0
	Landspreading (Dry)			
	Transport & spread		136.0	136.0
	chemical conditioning & vacuum filters	830.0	57.0	887.0
Total cost of alternative		830.0	193.0	1,023.0
	Landfilling			
	Transport & placement		378.4	378.4
	chemical conditioning & vacuum filters	830.0	57.0	887.0
Total cost of alternative		830.0	435.4	1,265.4
	Disposal Ponds (ash)			
	Transport & ponding		122.6	122.6
	chemical conditioning, vacuum filtration, & incineration	2,530.0	1,110.0	3,640.0
Total cost of alternative		2,530.0	1,232.6	3,762.6

EFFECTS

	Decrease in dissolved oxygen	Increase in acidity	Increase in alkalinity	Increase in ammonia	Increase in heavy metal
Land spread (wet)	possible	possible	none	possible	possible
Land spread (dry)	possible	possible	possible	possible	possible
Landfilling	possible	possible	none	possible	possible
Disposal pond (ash)	none	none	possible	none	possible

6.6.2 Septage

About 20 percent of the CROG population is currently served by septic tanks. This usage will decrease somewhat as sewer collection service is extended to outlying areas.

6.6.2.1 Number of Septic Tanks - Approximately 84,000 households in CROG are served by individual septic tanks. Most of these are located in Quincy, Madison, and Washington Counties. The average volume of wastewater directed to the septic tank system is estimated at 135 gallons (0.51 m^3) per day per household. Average solids content is about 4 percent (See Section 2.2).

6.6.2.2 Current Disposal of Septage - Septic tanks must be cleaned about every 3 years. When the tanks are cleaned, the partially stabalized waste is transported in tank trucks to the nearest wastewater treatment plant, where it undergoes stabilization, dewatering, and disposal by land application (See Section 3). Fortunately the wastewater treatment plants are not overloaded and can therefore accommodate the septage. Agricultural and pasture lands in the outlying areas of CROG can accommodate the septic tank wastes for the next 20 years.

Land Application of Septage

Soils in Madison, Washington, and Quincy Counties are acceptable for land application of stabilized septic tank wastes; most of the soil is fairly impervious. Ground water level ranges from 10 to 15 feet (3.05 to 4.75 M) below the surface. The population density in the three-county area is relatively low. Since all of the septic tank waste and most of the wastewater volume is from domestic population, there is little danger of contamination of soil or ground water by heavy metals.

The average cost of treatment and disposal of septage by this method is $8.91 per year per household. This cost includes annual amortized capital and all operation and maintenance.

Landfilling

Landfilling of treated septic tank wastes (stabilized at 20% solids) is possible at the several small sanitary landfills in CROG. Most of the landfills take solid waste in the form of household refuse. However, leaching into ground water is possible and suspected. Therefore, further leaching must be prevented. Water quality could be projected from further degradation if liners are installed as well as proper grading to prevent runoff and erosion. At the same time this BMP would necessitate the use of a monitoring system to detect any unsuspected contamination of ground or surface waters. Thus the possibility of a long term irreversible impact could be avoided. Landfill costs range from $3.05

per ton for a 1,000-ton per-day ($3.36 per ton for 1,000 metric tons per day) facility to $9.25 per ton for a 100-ton-per-day ($10.18 per ton for 100 metric tons per day) facility. This cost includes capital expenditure, annual operating and maintenance costs, and amortization but excludes the cost of land and the cost of transport to the landfill site.

6.6.3 Water Treatment Sludges

The CROG area has seven major water treatment plants of capacity greater than 1 mgd (3,800 m^3/day). Locations of these plants are shown in Figure 6-5. Besides the seven plants, which are publicly owned, several privately owned, noncommunity systems serve campgrounds, motels, and mobile home parks. The smaller of these plants generate relatively insignificant quantities of sludge (See Section 2.3).

6.6.3.1 Present and Projected Sludge Quantities for the CROG Area Population - Consultants retained by CROG estimate that in 1975 approximately 1,000 wet tons (908 metric tons) per day of sludge was generated. Generation is projected to increase to about 3,000 wet tons (2,724 metric tons) per day in 1995.

6.6.3.2 Water Treatment Plants in CROG - Of the seven major water treatment plants in CROG, three use the lime-soda softening process and four use coagulation.

Some localities within the CROG area are without adequate supplies of water. Although sources of water are plentiful over the area as a whole, they are unevenly distributed. Surface waters constitute the primary source of water, providing about 75 percent of the total amount of water processed. It is estimated that this ratio will hold during the planning period (1970-1990).

6.6.3.3 Alternative Management Practices - Until recent years all of the water treatment plants in CROG discharged their sludges into the nearest watercourse. Current stream pollution regulations are curtailing this practice and it is anticipated that by 1985 all water treatment plants, large and small, will be required to refrain from discharging any wastes into the rivers and streams.

Some of the smaller plants still discharge their sludges directly into Main City's sewage system. This practice must soon be abandoned, however, since Main City's wastewater treatment plant will no longer be permitted to discharge sludge to the river.

Therefore, Plant No. 1 was suggested by CROG's Citizen Advisory Committee (CAC) as an example for consideration of management practices. This plant has a capacity of 130 mgd (494,000 m^3/day), and serves about

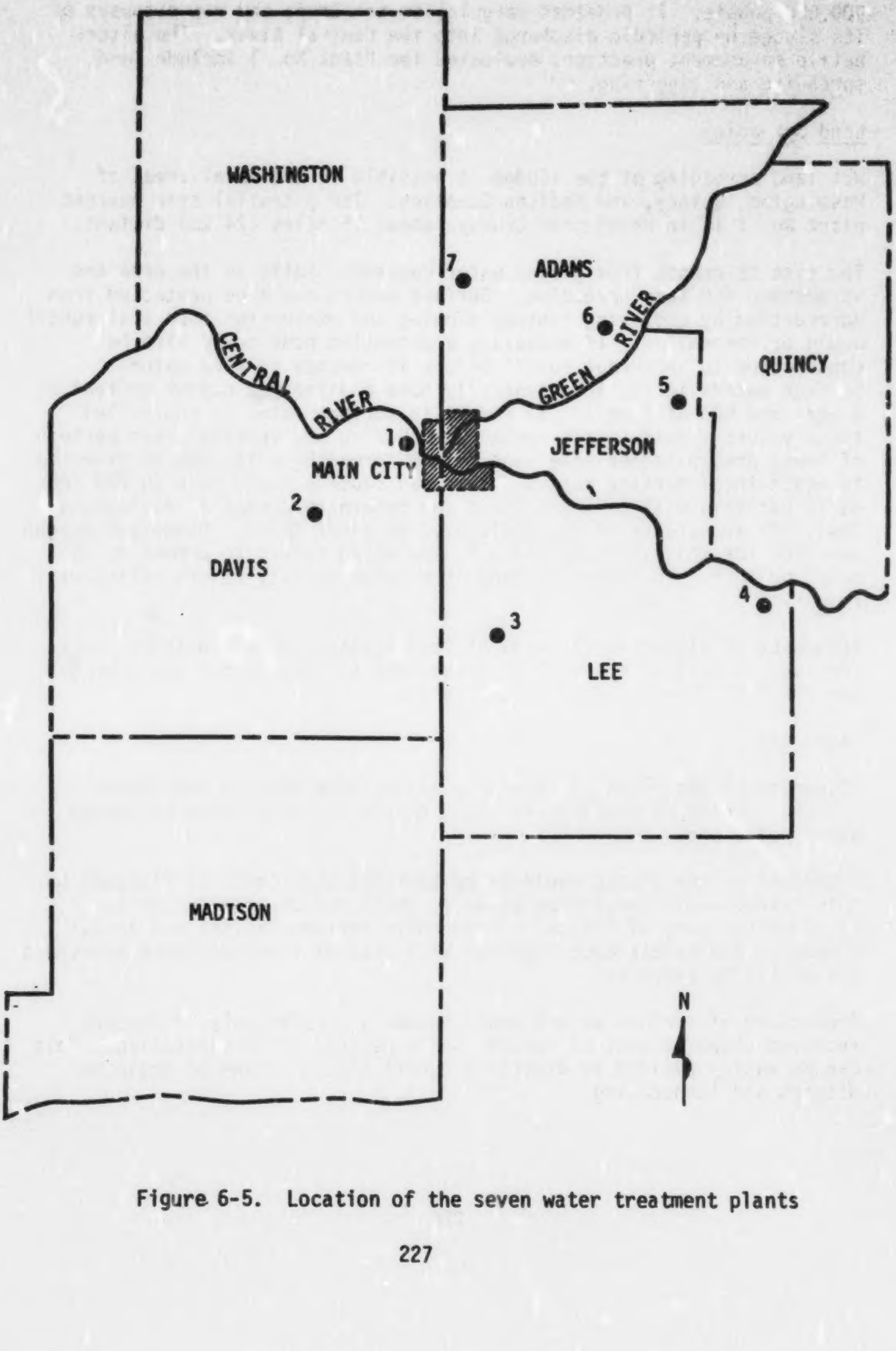
WASHINGTON
7
ADAMS
6
GREEN RIVER
CENTRAL RIVER
QUINCY
5
1
JEFFERSON
MAIN CITY
2
DAVIS
4
3
LEE
MADISON
N

Figure 6-5. Location of the seven water treatment plants

900,000 people. It provides coagulation treatment and now disposes of its sludge by periodic discharge into the Central River. The alternative management practices evaluated for Plant No. 1 include land spreading and lagooning.

Land Spreading

Wet land spreading of the sludge is possible in the rural areas of Washington, Quincy, and Madison Counties. The potential site nearest plant No. 1 is in Washington County, about 15 miles (24 km) distant.

The site is remote from ground water courses. Soils in the area are acceptable for land spreading. Surface waters could be protected from degredation by employing contour plowing and excavation such that runoff would be controlled. If necessary a detention pond could also be constructed to intercept runoff before it reaches surface waters. Surface waters in the area generally have a dissolved oxygen content of 9 mg/l and BOD of 3 mg/l. If runoff to surface water is controlled these values should remain unchanged. During and shortly after periods of heavy precipitation some runoff from spreading sites may be expected to reach local surface waters. This may cause a rapid rise in BOD (80 mg/l) but this will be short lived and return to normal in 48 hours or less. An appearance of NH_3 would also be short lived. Dissolved oxygen may drop for this short period but also would return to normal in 48 hours or less. Therefore no long term water quality deterioration will result.

Transport of sludge to the area of land application would be by truck. The average cost of disposal of the sludge by this method would be $19 per ton ($20.9/metric ton) of dry solids.

Lagooning

Lagooning of the sludge is possible at the same site in Washington County. Lining of the lagoons would reduce the likelihood of ground water pollution.

Transport of the sludge would be by tank trucks. Costs of disposal by this method would range from $1.90 to $6.65 per dry ton ($2.09 to $7.32/metric ton) of solids. These costs include capital and annual operating and maintenance together with cost of short-distance transport (generally by pipeline).

Protection of surface waters would become a problem only if lagoons received undue amounts of runoff during periods of precipitation. This can be easily avoided by diverting runoff through means of drainage ditches and landscaping.

The employment of either land spreading or lagooning of sludge at Plant No. 1 is expected to increase the water quality of the stream presently receiving the sludge. BOD is expected to decrease by 40 percent and SS by 50 percent. Total coliform is projected to decrease by 85 percent thus returning the stream to near normal conditions.

6.6.4 Municipal Refuse

In years past municipal refuse generated in the CROG area was disposed of by open dumping and open burning. With the enactment of various State and Federal laws, however, these methods became illegal. Though some open burning and open dumping continued in isolated areas, the more heavily populated municipalities began to use sanitary landfills. Main City and its suburbs in Lee, Davis, Adams, and Jefferson Counties are now experiencing further problems. The landfill that serves this populated area has only 8 years operating life remaining. The nearest site for location of a new landfill is about 20 miles (32 km), distant. Thus trucking of refuse will require a 40-mile (64 km), round trip, whereas only a 4-mile (6.4 km), round trip is currently required. The increased transport costs, coupled with ever increasing tonnage of refuse and resultant operating costs will cause a drastic increase in total disposal costs. Planners in the CROG area have therefore decided to investigate other possible means of municipal refuse management.

6.6.4.1 Municipal Waste Generation - It is estimated that the urban population served by the landfill is 1,260,747, with yearly generation of 1,035,388 tons (940,133 metric tons) of municipal refuse. The per capita generation rate is 4.5 pounds (2.04 kg) per day. Table 6-8 lists the 1975 and projected 1995 waste generation tonnage for the urbanized areas (See Section 2.4).

Table 6-8. PRESENT AND PROJECTED MUNICIPAL REFUSE TONNAGES FOR THE URBANIZED AREAS OF CROG

County	Tons/year[a]	
	1975	1995
Adams	93,018	225,858
Davis	167,726	257,462
Jefferson	596,553	964,496
Lee	178,091	482,925
Total	1,035,388	1,930,074

[a] Estimated using the per capita generation rate of 4.5 lb/day (2.0 kg/day).

6.6.4.2 Possible Disposal Techniques - Several disposal techniques were investigated to determine the best management practice: 1) baling and compacting with subsequent landfilling of the bales, 2) incineration, 3) shredding and material separation followed by composting and spreading of the compost, and 4) shredding and material separation with subsequent sale of the recovered commodities for reprocessing and combustion in industrial or utility boilers as a supplement fuel (See Section 3).

After investigation, all but one of these alternatives were eliminated. Baling and compacting would extend the life of the sanitary landfill by only 4 years, which is not long enough to justify the high capital investment. Incineration was eliminated because of high capital costs and detrimental effect on local air quality. Also, incineration would require an ash lagoon in which to thicken the slurried ash before it is landfilled. Though some volume reduction would be realized, use of the lagoons would extend the life of the landfill by only another 8 years (16 years total life). Composting was eliminated because a market for the compost could not be assured and the capital costs are high.

Manufacture of a supplemental fuel after shredding and material separation appeared to be the most promising management practice for the urbanized area. Various area specific circumstances contributed to this situation. Solid waste collection in the area is controlled by three private haulers and one public system of Main City, all of whom agreed to deliver their municipal refuse to the central processing center at a cost equal to or lower than tipping charges at the landfill. Several large industries committed themselves to purchase of manufactured fuel for the next 20 years. The cost on a million Btu basis would be about half of their current fuel cost. In addition, all ferrous metals recovered would be purchased by a local steel manufacturer for remelt. With these substantial reductions in volume of waste for disposal, the life of the landfill would be extended by as much as 24 years (32 years total) and a secondary use would be found for as much as 80 percent of the muncipal refuse. Moreover, because the residual waste for landfilling would be relatively more inert than raw refuse, any leachate should be less harmful.

Landfill Operation

Continued use of the landfill for residuals disposal will require only minor changes. Soils at the landfill site are mostly silty clays with minimal sand. For protection of ground water quality, a 2-foot-thick (0.6 m) layer of clay will be compacted on the bottom and sides of the landfill to form an impervious liner. As portions of the landfill are completed the final cover layer will be laid such as to retard penetration of runoff into the landfill site thus reducing the amount of leachate generated by the landfill. The land adjacent to the landfill will be graded to divert overland runoff.

Costs and Revenues from the Recovery Facilities

Estimated capital cost of shredders, mechanical separators, peripheral equipment, buildings, and facilities, as well as operating and maintenance costs and income revenues are as follows:

Capital cost (Amortized at 8% over 20 years level debt service)	98,569,000
Annual capital cost	4,928,450
Annual O&M	5,104,463
Total Annual Cost	10,032,913
Annual cash inflow from tipping charges and fuel sales	13,967,383
Net cash from Annual Operation	3,934,470

6.6.4.3 Rural Municipal Waste Management - CROG planners also sought better management of refuse generated in the rural areas. Though the efforts of county commissioners and the CAC all open dumps and burning was discontinued and acceptable areas for landfills were located (Figure 6-6). One landfill was located in the northeast corner of Madison county to serve the rural population of Lee and Davis counties and the entire population of Madison county. The landfill is designed for 20-year life, with a 2-foot-thick clay liner. A second landfill of similar design was located in northwest Adams County to serve the rural areas of Adams County and all portions of Washington and Quincy Counties. Construction and operation of both landfills will be similar to that discussed in Section 6.4.2.1 in order to reduce and control the leachate in the landfill. Costs for these two landfills are as follows.

Landfill location	Tons/ day	Annual[a] capital	Annual O&M	Total cost/ton
Madison County	157	$111,553	$186,060	$6.08
Adams County	276	$143,774	$221,341	$4.24

[a] Amortized at 8% over 20 years level debt service.

In summary, the Best Management Practice for disposal of municipal refuse in the CROG area consists of a blend of several management techniques: (1) volume of wastes is reduced by shredding and material

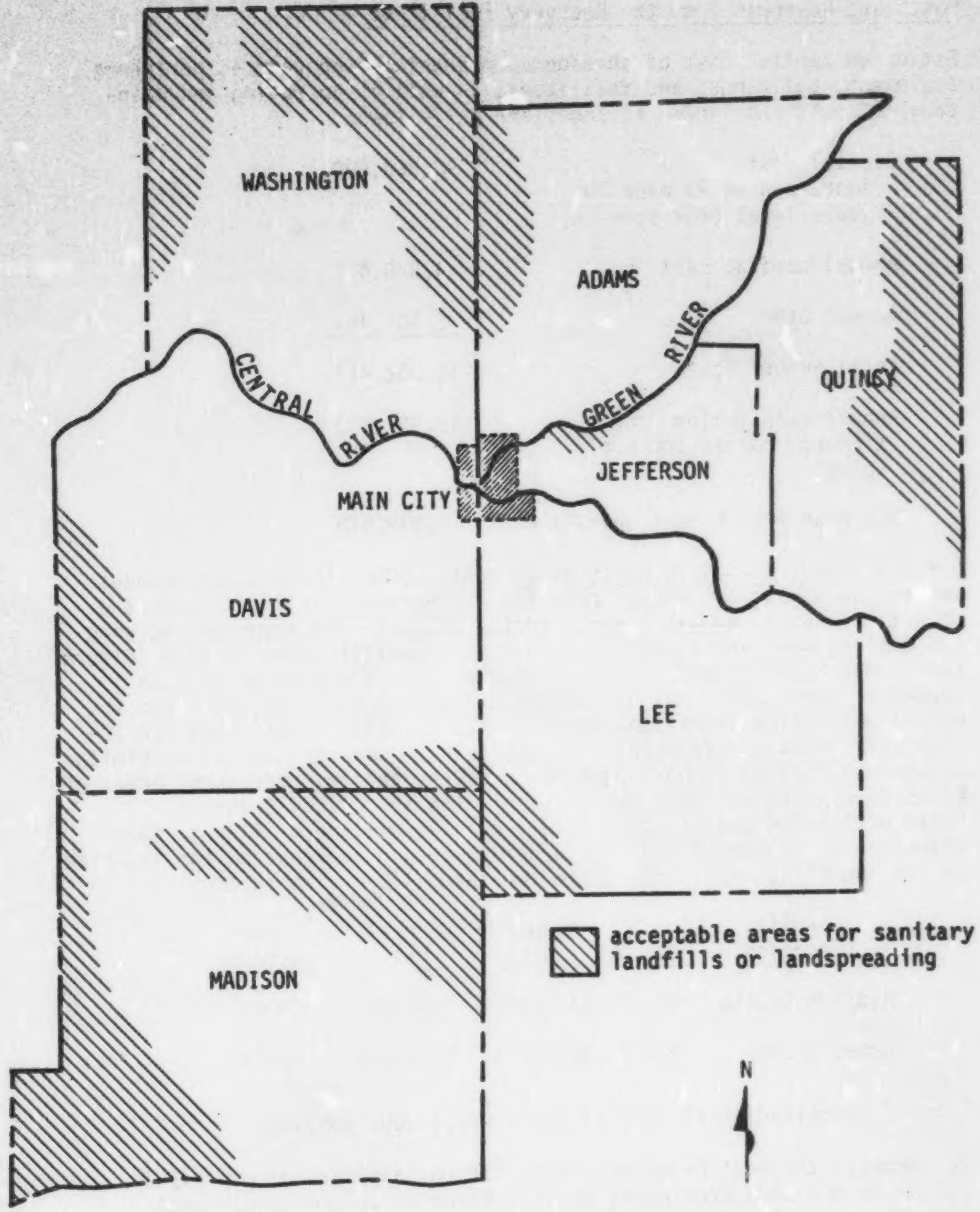
WASHINGTON
ADAMS
CENTRAL RIVER
GREEN RIVER
QUINSY
JEFFERSON
MAIN CITY
DAVIS
LEE
MADISON
▨ acceptable areas for sanitary landfills or landspreading
N

Figure 6-6. Areas containing sufficient loess, alluvium, and glacial drift to allow for landfilling and land spreading.

separation, (2) materials are recovered for reprocessing or combustion values, (3) operation of the present landfill is improved by provision of a clay liner and by grading to divert runoff from the site, and (4) open burning and dumping in rural areas is discontinued and two well-designed landfills constructed for disposal of wastes in those areas.

The blending of several management techniques to form this BMP will also aid greatly in the preservation of water quality and in particular, ground water. Table 6-9 lists the range of ground water characteristics found in the area of the landfills. If the landfills are properly operated this quality should remain unchanged.

Table 6-9. GROUND WATER CHARACTERISTICS AT THE LANDFILL SITE

Characteristics	Value range
Conductivity	1700-1900 μ mhos/cm
Chlorides	260-300 mg/l
Total Hardness	345-390 mg/l as $CaCO_3$
Calcium	140-185 mg/l as $CaCO_3$
Alkalinity (methyl)	490-550 mg/l as $CaCO_3$
Caliform (Std.)	0-25 colonies/100 ml
Nitrite - Nitrogen	<0.1 mg/l
Ammonia - Nitrogen	<1.0 mg/l
Nitrate - Nitrogen	3.0-5.0 mg/l
COD	3.0-5.0 mg/l

6.6.5 Combustion and Air Pollution Control Residuals

Electrical power stations are one of the major sources for generation of combustion residuals in the CROG area. Most of the power stations are coal-fired, and all operate high-efficiency fly ash control systems. Therefore, ash is the basic residual to be dealt with by these plants (See Section 2.5).

6.6.5.1 Residual Ash Generation - The largest power plant in the CROG area is the Abet Electric Plant located on the Central River, west of Main City in Washington County (Figure 6-7). The plant has a rated capacity of 1,000 megawatts (MW), consisting of one 500-MW unit and two 250-MW units. Ash residual from combustion is basically of two types, bottom ash and fly ash. Approximately 200,200 wet tons (182,000 metric tons) of bottom ash at 50 percent solids is produced annually. In addition, 196,000 dry tons (178,000 metric tons) of fly ash is generated annually. Also 1,454,000 tons (1,320,232 metric tons) of sludge at 50 percent solids is generated annually from SO_2 emission control equipment.

6.6.5.2 Residual Ash Disposal - All residual ash and sludge generated is now disposed of in an on-site lagoon. The slurried bottom ash and sludge is pumped to the lagoon, and the fly ash is transported by truck (See Section 3). This means of disposal is not considered acceptable for several reasons. The lagoon is located on a flood plain and is not lined. Periodic flooding causes the ash to wash into the river. Further, the possibility of ground water contamination is high. Lastly, the lagoon will be filled to capacity in 4 years.

6.6.5.3 Proposed Management Practices - After detailed investigation planners in the CROG area as well as State officials and the CAC developed a Best Management Practice based on two methods of disposal: (1) use of fly ash as a bedding material in construction of roads and sewers, and (2) improved lagooning of bottom ash and sludge. Because the CROG area is developing rapidly, new roads are under construction and old ones are being widened and repaired. In addition, new sewage lines are being laid and old ones replaced. These activities require large volumes of bedding material. Since fly ash makes for excellent bedding, CROG planners decided to propose the power plant fly ash for this purpose. In this way a residual is recycled, and the total volume requiring disposal is reduced. A subcommitte of CAC was formed to negotiate an agreement among highway and sewer district representatives with Abet management to implement this BMP.

The presently operated lagoon will be shut down. A new lagoon for disposal of bottom ash and sludge will be located approximately 5 miles north of the present lagoon, away from the flood plains. Soils in the area are acceptable for lagooning of the ash. The lagoon will be filled to capacity, the excess water skimmed off, and the lagoon covered with soil. Disposal will then be made in a second newly constructed lagoon. Lagoons will be clay-lined and designed for 20-year life. Cost of the lagooning operation is estimated as follows:

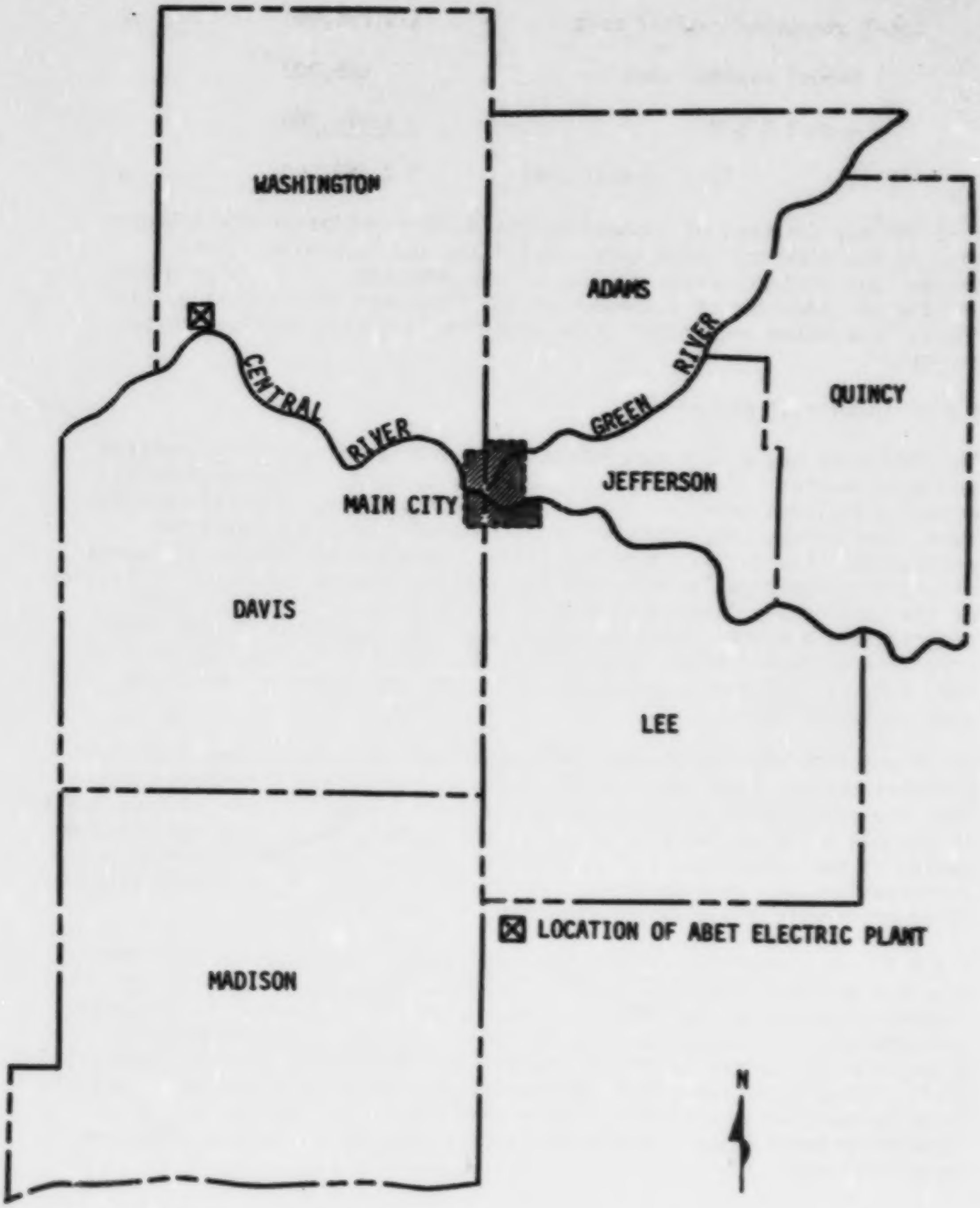
WASHINGTON
ADAMS
QUINCY
CENTRAL RIVER
GREEN RIVER
MAIN CITY
JEFFERSON
DAVIS
LEE
MADISON
⊠ LOCATION OF ABET ELECTRIC PLANT
N

Figure 6-7. Location of the Abet Electric power plant.

Total amortized capital cost	$13,290,000
Annual capital cost	665,000
Annual O & M	1,515,000
Total annual cost	$ 2,280,000

This BMP for disposal of combustion residuals exemplifies the integration of two disposal techniques - recycling and lagooning - into a system that protects water quality of the CROG area. By applying this BMP further addition of suspended solids from this source will be virtually eliminated and ground water contamination will continue to be prevented.

6.6.6 Industrial Wastes

The CROG area has a high concentration of industrial activity centered in four counties: Jefferson, Lee, Davis and Adams. Major industrial activity includes chemical processing, electroplating, plastics manufacture, food processing, consumer product manufacture, and herbicide production. Typically, these facilities discharge wastewater effluents directly to municipally owned and operated wastewater treatment facilities. Of the total daily flow treated by these facilities, the industrial contribution averages 30 percent. Some of the industries in the CROG area face extremely high sewage surcharges based on typical analyses of COD, BOD, pH, and suspended solids made near the source of discharge (See Section 2.6).

It is possible that by January 1977 industries will be required to pretreat before discharge to municipal sewer systems. With this occurance the practice of waste exchange may become feasible (See Section 3.5.4). An example of waste exchange might be the exchanging of acid and alkaline wastes by two industries for purposes of neutralization. Also resource conservation such as reduction of hydraulic flows to reduce quantities to be pretreated may also be practiced.

6.6.6.1 Industrial Wastes Residual Generation - Planners in the CROG area are making a concerted effort to reduce pollution closer to its source. Several of the CROG area industries are attempting to pretreat portions of their wastes on-site to reduce the level of contaminants going down the sewers to the wastewater treatment plants. Such pretreatment still creates residuals, which must be treated and handled separately from the wastewater effluent. Other residuals are generated in certain chemical process steps. Among the major residuals created by CROG area industries are:

- Distillation bottoms/tops
- Oily waste residuals
- Lime sludged materials
- Spent filter media
- Spent catalysts
- Dissolved salts
- Tank storage farm runoffs
- Cleanout residuals from process equipment washes

The amount of residuals generated by the CROG area industries is not well-documented. A conservative estimate is 50 to 75 tons per day.

6.6.6.2 Industrial Waste Residual Disposal - Most of the CROG industries are disposing of their residual wastes on an individual basis. Many of the CROG industries operate chemical landfills on-site at the manufacturing facility. Such landfills are often unlined and are located on or near floodplains, in sandy soils with high slope, and at minimum levels above ground water. Some CROG industries are attempting to incinerate their residuals, but such operations are energy-expensive and lead to critical discharge of obnoxious and odorous gases. In addition to the landfill and incineration practices, some industries are paying $1000 per truckload for hauling of less than a ton of residuals to a landfill site across the State line. Industries paying for this service have no idea where the residuals are disposed of, and are concerned that the adjacent State officials may close the landfill.

These disposal practices are costly and are not environmentally safe. One industrial spokesman indicates that whereas it costs only $2.50 per ton ($2.75/metric ton) for him to dispose of his municipal refuse (garbage, waste corrugate, packing materials, glass, etc.) it costs $75 to $100 per ton ($83 to $110/metric ton) to dispose of industrial refuse in environmentally inadequate ways.

6.6.6.3 Proposed Industrial Residuals Disposal - The CROG has met with major company officials from the four-county industrialized sector of CROG to formulate a regional approach to handling of all industrial wastes. The regional approach centers on a block of land located in Madison County donated to the County in the estate of a wealthy resident. It is stipulated that the land must be utilized by the County to establish a source of income for benefit of the people of Madison County. Such derived income would be used for building recreational areas, public transportation facilities, and other amenities generally unavailable to the rural people of Madison County.

The gently sloping land with highly impermeable soil is located away from the floodplains. It is 2 miles (3.2 km) from the nearest concentration of residents. The ground water table even at peak periods seldom rises above 16 feet below the surface. Further, the site is accessible to highway transportation and can be reached in less than an hour from any industrial site in the four-county area. CROG hopes to eliminate individual chemical landfill operations by persuading Madison County officials to establish a regional industrial chemical landfill on this land.

This would be a positive step in the direction of water quality improvement. Though it is not collectively known what the water pollution load is from the various industries it is suspected to be more than marginal because of locations and mismanagement of individual lagoons and landfills. The use of one centralized landfill, properly located and operated, would be a definite plus to water quality improvement.

Based on 100 tons/day, operating 312 days a year, CROG's consultants believe that the industrial waste residuals generated over the next 20 years can be adequately landfilled on less than one-third of the land available in Madison County. Industrial growth in the CROG area has stabilized; current projections indicate only minor industrial expansions over the next 20 years. CROG has recommended the establishment of a service group, formed jointly by each county and operated by a private contractor, to run the regional landfill (See Section 6.4). The service group will be responsible for:

- Safe and proper management of the chemical landfill site.
- Regular analyses in on-site laboratories of samples from monitoring wells.
- Segregation on the site of hazardous from nonhazardous residuals.
- Record keeping, materials receipt, billing, and other administrative functions.

The industries will assume the cost of transport to the site and will provide the service group with detailed analytical characterizations of their residuals. Although responsibility for operation of the landfill will be the service group's, industries will be held liable for any problems resulting from unadequate characterization of their inputs to the landfill. Since the industries will be hauling wastes to the chemical landfill, any liabilities in this step rest with the hauler and the industry (See Section 4).

Table 6-10 summarizes capital expenditures and operating and maintenance costs associated with the proposed chemical landfill. One of the industrial representatives familiar with a large chemical landfill operation near Charleston, West Virginia, has stated that costs were as high as $50 a ton, not including transport. CROG staff has determined that on the basis of a high input rate per day and the economic savings of a

Table 6-10. ESTIMATED ORDER-OF-MAGNITUDE COSTS TO OPERATE THE CROG AREAWIDE CHEMICAL LANDFILL SITE

Tons/day	Tons/year[a]	Capital expenditure[b,c]	Total amortized capital costs[d]	Annual amortized capital costs	Annual O&M[e]	Total annual cost	Unit cost per ton
100	31,200	2,710,108	5,436,476	271,823	454,195	726,018	23.27

[a] Based on 312 days/year, 6 days/week, 8 hours/day.

[b] All costs adjusted to represent 1976 dollars (i.e., 1976 = 100).

[c] Based on an in-situ compacted density of 800 lb/yd^3, 12 feet operating depth, and site efficiency of 85% (6582 tons/acre). Includes site work, scales, roads, fences, structures, materials, installation, surface, surveys, subsurface inventigations, operating equipment, contractor's overhead, a 45 mil Hypalon lining, monitoring wells, and profit, etc. Does not include engineering and legal fees, contingencies, resource recovery, land costs, collection and haul to the landfill, etc.

[d] Amortized at 8% interest, 20 year term, level debt service.

[e] Includes salaries and overhead, fuels, utilities, equipment maintenance and replacement, analytical services, etc. Does not include collection and haul to the landfill, etc.

regionalized operation, use of the proposed CROG facility should cost only half as much on a unit basis as individual operation of facilities with small daily inputs.

The State office of hazardous waste management intends to close all landfills located on individual industrial properties. CROG planners have met with State officials, and have received full sanction and support for a regional chemical landfill. The CROG study shows that nearly $2.00/ton ($2.20/metric ton), of the billed charges will be returned to the County to fulfill the requirements of the late benefactor's will. The County will receive more than $60,000 per year for use to improve the life and well-being of its citizens.

The efforts of the CROG planning staff have successfully brought together local government and industry to create a regional entity to handle the CROG industrial waste residuals. By overwhelming vote of representatives from industry, from Madison County, and from other agencies in the CROG area, the go-ahead has been given to develop the regional chemical landfill.

The BMP for disposal of industrial wastes has resulted in this instance from problem definition and technical evaluation, followed by administrative efforts to achieve cooperation among groups having diverse interests. The legal/institutional aspects of the project demanded considerable skill in liaison among these groups to achieve a program that is beneficial to the local industries, to the citizens of Madison County through increased revenues to be expended on their behalf, and to all citizens of the CROG area through improvement and protection of water quality.

6.6.7 Feedlot Wastes

The livestock industry in CROG has evolved from small individual farm operations to large-scale confinement feeding enterprises. Development of confined feeding in CROG began in the mid-1950's. Since then the number of feedlots has increased by 5 percent and the number of animals in confinement, by 60 percent.

Because of the advantages of confinement feeding it is predicted that the trend will be towards fewer but much larger feedlots (See Section 2.7). Livestock producers will therefore be concentrating larger volumes of livestock wastes into smaller areas. This problem will be compounded by the progressively rising rate of urban growth in the CROG region, since urbanization will reduce the amount of land available for expanding feedlots and at the same time increase public contact with feedlot operations. Disposal of livestock waste, therefore, is a serious problem necessitating immediate action. The CROG CAC has begun considering alternative plans with feedlot operators for developing sound management practices for the ultimate utilization and disposal of animal wastes.

6.6.7.1 Feedlot Types, Locations, Numbers, and Sizes - Beef cattle and swine are raised by confinement in CROG. Feedlots are operated in Madison, Quincy, and Washington counties. All of the lots in Madison County, and most of those in Quincy and Washington counties, are located in exclusively agricultural areas. A few feedlots in Quincy and Washington Counties, however, are close to zones of increasing urban growth. In addition, several of the lots of these two counties are located near major lotic communities.

Of the 51 feedlots in CROG (30 beef, 21 hog, as shown in Table 6-11), 23 are located in Madison County. Beef cattle feedlots predominate in all three counties.

In about 75 percent of the feedlots, livestock populations are 1000 head or more. Each county includes several smaller lots (less than 1000 head per lot), but most of the small lots are located on the flood plains of Washington and Quincy Counties.

Table 6-11. NUMBER OF FEEDLOTS BY ANIMAL TYPE AND COUNTY

	Feedlot number	
	Swine	Beef cattle
Washington County		
Less than 1000 head	3	2
Greater than 1000 head	5	7
Subtotal	8	9
Quincy County		
Less than 1000 head	2	3
Greater than 1000 head	2	4
Subtotal	4	7
Madison County		
Less than 1000 head	2	0
Greater than 1000 head	7	14
Subtotal	9	14
Total	21	30

6.6.7.2 Quantities of Livestock Wastes - The present population of cattle and hogs in the three counties of CROG is 300,000 head (Table 6-12). Projections indicate that by 1995 the population will approach 400,000 head.

Annual production of feedlot manure can be determined by multiplying the numbers and types of animals in Table 6-12 by their respective daily manure production values. The current annual production of manure (feces and urine) in CROG is approximately 1.9 million tons (1.7 million metric tons) (Table 6-12). Manure quantities are expected to exceed 2.5 million tons (2.3 million metric tons) annually by 1995.

6.6.7.3 Problems Associated with Livestock Wastes - The major problems arising from livestock wastes are due to the high total solids content and large BOD and COD values. It is estimated that BOD concentrations of livestock manure are 100 to 300 times greater than those of untreated domestic sewage and that COD values are 100 to 400 times greater.

Microbial organisms in animal wastes present additional problems. Some investigators have estimated that daily per capita discharge of total coliforms in feces range from 5×10^9 to 10×10^9 cells for cattle and hogs. Many of these cells are pathogenic. Color and odor are additional but relatively minor problems.

Investigations have shown that after heavy storms the BOD values increase substantially in the Central and Green Rivers at points where feedlots are adjacent to the water. Measurements taken 15 hours after a 1-inch rainstorm at a site 1 mile below a feedlot on the Central River showed contents of 95 ppm BOD and less than 1 ppm oxygen. Such conditions resulting from feedlot runoff have caused several fish kills in Washington and Quincy Counties.

In addition to the increase in BOD values in surface waters after storms, enormous increases in fecal bateria counts have also been recorded. As mentioned earlier many of these micro-organisms are pathogenic.

The potential for ground water contamination from runoff is relatively great because of the high permeability of rock materials in the counties of CROG (See Section 4).

6.6.7.4 Compliance Requirements - Both local and State environmental and public health standards apply to feedlot wastes. Generally, the regulations state that feedlot wastes should not be discharged into public waterways unless they are pretreated sufficiently to meet the established legal standards.

Table 6-12. PROJECTED ANNUAL LIVESTOCK POPULATIONS AND MANURE PRODUCTION

Animal type	1975	1980	1985	1990	1995
Beef Cattle					
Number	200,000	210,880	224,580	238,360	264,620
Manure[a], tons	1,934,500	2,039,737	2,172,250	2,305,537	2,559,537
Swine					
Number	100,000	105,440	112,290	119,180	132,310
Manure[b], tons	18,740	19,759	21,043	22,334	24,795
Total number	300,000	316,320	336,870	357,540	396,930
Total manure tons	1,953,240	2,059,496	2,193,293	2,327,871	2,483,332

[a] Daily beef cattle manure production = 53 lb per animal.

[b] Daily swine manure production = 9.8 lb per animal.

In addition to State and local regulations the U.S. EPA has recently established several criteria for defining feedlots as point sources that require a permit from the National Pollutant Discharge Elimination System (NPDES) (40 CFR 125). Most of the feedlots in CROG may be affected by criteria that defines a feedlot as a point source. In addition, several of the small lots in Washington and Quincy Counties would be classified as point sources because they are located on the floodplains and involve discrete discharges to a navigable stream.

6.6.7.5 Current Management Practices for Handling Livestock Wastes - The predominant method of handling cattle feedlot manure in the CROG counties involves anaerobic digestion with lagoons to catch the runoff. The topography of the region permits gravity flow. Excess solids that accumulate on the floor of the feedlots are spread on crop lands for recovery of fertilizer values. (The total quantity of raw manure produced in CROG in 1975 was equivalent to 15,800 tons (14,364 metric tons) of nitrogen, 4,780 tons (4,340 metric tons) of phosphorous, and 10,600 tons (9,625 metric tons) of potassium). Periodically the lagoons are drained and these wastes are irrigated to the land.

Management of hog manure in CROG involves the collection of wastes in a shallow pit with an overflow to a lagoon, which is irrigated to crop land when weather permits. When weather prevents irrigation the overflow is stored in the lagoon. The collection pits are drained with a manure tanker periodically to remove settled solids.

Because of weather conditions, cropping practices, and availability of labor, accumulated manure cannot be placed on fields daily. The required temporary storage is usually accomplished simply by permitting the manure to accumulate in the buildings or on feedlots.

The farming equipment used for other agricultural operations is also used to handle feedlot manure. The wastes are removed and spread by means of tractors, manure spreaders, and small irrigation equipment.

Some of the feedlots are encircled with dikes, terraces, or diversion channels to control runoff. In the areas of the CROG region where limestone and sandstone are predominant, synthetic or earthen liners are used to retard the migration of hazardous materials into aquifers (See Section 3).

6.6.7.6 Typical Cost of Current Management Practices - Unit input costs for wastes from beef cattle range from $0.82 per wet ton ($0.90/metric ton) for a 100-head feedlot to $0.33 per wet ton ($0.36/metric ton) for a 20,000-head lot. Costs for swine wastes range from $5.93 to $3.30 per wet ton ($6.53 to 3.63/metric ton) respectively for 250- and 1,000-head lots.

6.6.7.7 Potential Management Practices for Handling Livestock Wastes - Some of the potential management practices for handling of livestock wastes warrant further consideration. Among these, the recovery and refeeding of foods and nutrients in fresh manures is a potential best management practice. It would significantly reduce the volumes of solid and liquid wastes, with potential economic benefits and conservation of feed grains.

The industrial waste treatment method involving coagulation and clarification coupled with vacuum filtration and/or centrifugation also has potential for adaptation to treatment of agricultural wastes.

The overall management practices for handling livestock wastes in CROG contribute to water quality degradation and present high potential to continue particularly where feedlots are located near surface water. Therefore, development of BMP's for collection and treatment of feedlot wastes should continue (See Section 6.6.7.5). In addition, fundamental change in permitted location of feedlots in CROG is required. Measures should be taken to prohibit further location of feedlots on floodplains and other water quality sensitive areas and to require removal of existing feedlots to less sensitive areas. Preventive measures in the future may take the form of changed zoning provisions. Corrective measures may involve promulgation and enforcement of standards contained in EPA's proposed feedlot regulations (40 CFR 125). Removal of feedlots from flood plains would completely eliminate contaminents from those point sources.

In the interim, the requirement for compliance with standards at the local, State, and Federal levels will provide some protection for the CROG water quality.

An ultimate BMP for handling of feedlot wastes probably will entail development of recovery/refeeding and waste treatment technologies, perhaps along with cooperative enterprise among livestock producers for centralized processing facilities.

6.6.8 Mine Wastes

Located in the southeast corner of Madison County is a small 2,000 ton (1,816 metric ton) per day coal strip mine. Though this mine is not large by relative standards, it generates solid and liquid wastes in substantial amounts (See Section 2.8). Disposal of these wastes has been a problem almost since the start of the mining operation. Overburden and processing wastes from the stripped areas have been piled in mounds. Runoff from the mounds and the stripped areas has seriously polluted a nearby receiving stream. As a result of a sharp decrease in the pH of stream water most vegetation and aquatic life has been eliminated for 2 miles (3.2 km) downstream from the point of discharge.

6.6.8.1 Corrective Action - Numerous complaints were registered from local citizens, fishing and outdoor clubs, as well as the CAC concerning the impacted stream. CROG area officials realized that some corrective action must be taken to prevent further adverse environmental impact. After conducting surveys of the strip mine area, the CAC met with engineers, planners, state mine officials, an outside consultant, and the strip mine owners to decide on a recommended method for management of the mine wastes.

It was recommended that all areas thus far stripped be reclaimed by grading the stockpiles of processing wastes (estimated at 2 tons (1.8 metric tons) for every ton of coal mined), and overburden. At the same time grading will be done to divert runoff (estimated at 250 gallons/minute), to one local facility for treatment before release into the nearby receiving stream. The water treatment will consist primarily of pH adjustment and to reduce the acidity and retention in a settling pond to reduce the turbidity of the mine water. These fairly simple techniques are considered as a BMP for disposal of mine wastes until such time as the mine is depleted and more extensive reclamation and revegetation are performed.

It is expected that the receiving stream will adjust itself back to its normal pH value of about 6.5 and soon afterwards become repopulated with aquatic life. Costs for reclamation are estimated at $1.05 per ton ($1.16/metric ton) of processing waste. Chemical treatment is estimated at $1.46 per 1000 gallons (3785 liters). Total annual cost is therefore estimated at $1,283,800. The approach to, and the results of the technical BMP is clear. However, applying this BMP is constrained by costs to the mine operator since public funds are not available for reclamation. Moreover, these costs are probably unrecoverable because uneven application of the State Mine Reclamation Act will prevent the mine operator from raising coal price accordingly since other mine owners will become more competitive. Therefore, application of the BMP under these conditions appears unattainable.

Consequently, the CROG Board of Commissioners has decided to follow the recommendation of the CAC and to petition the State legislature for an improved Mine Reclamation Act and sufficient funds for its enforcement (See Legal/Institutional Section 6.6). Successful passage of the Act amendments and diligent enforcement will result in applying the desired BMP in CROG as well as throughout the State.

6.6.9 Dredge Spoil Residuals

Several portions of the Central River have been dredged extensively so that the river can be negotiated by heavy barges and other vessels. In the past hydraulic dredges have merely pumped the dredge spoils behind earthen dikes along the river bank. Spring floods have caused severe erosion of these earthern dams and subsequent erosion of the dredge materials.

6.6.9.1 Quantity of Dredge Spoil - Of particular concern is that portion of the Central River that enters into the CROG area to form the common boundary of Washington and Davis Counties. River water quality is becoming increasingly impaired as a result of erosion and subsequent runoff. The earthen dams containing dredge spoils have been severely eroded, while at the same time poor farming practices have also contributed heavily to erosion, runoff, and subsequent sedimentation and high suspended solids in the river. It is estimated that approximately 200,000 cubic yards (152,920 m^3) of spoil must be dredged to make the river safe for navigation (See Section 2.9).

6.6.9.2 Dredging and Dredge Spoil Disposal - The Army Corps of Engineers is responsible for maintaining navigable channels in the CROG area. The need for redredging the channel in this portion of the river was obvious, but disposal of dredge spoil posed a problem. Also, control measures were required to prevent rapid recurrence of sedimentation in the channel.

Preventive measures were integrated into the overall plan for management of dredge spoil residuals. Erosion from agricultural fields is being dealt with through joint cooperation of the Corps, the State Department of Conservation, and local farmers. By use of contour plowing, cover crops, drainage, and other practices, the farmers can prevent excessive and unnecessary erosion and runoff. In addition, the deposition of dredge spoil on the river banks has been discontinued. Earthen dikes were constructed in new areas above flood stage for deposition of the dredge spoil. Hydraulic dredges pump the spoils to that point.

Before the dredging began, samples of the sediments were taken from the river bottom and analyzed for potentially toxic heavy metals and nitrogenous materials. Since the analyses indicated no dangerous level of any of the constituents, the sediment was judged to be safe for land disposal and pose no threat to the ground water quality. The new disposal area lies about 0.13 mile (0.19 km) south of the river. Since the spoils apparently contain no dangerous constituents, the disposal area was not lined.

6.6.9.3 Estimated Costs - Cost of dredging operations is estimated at $118,000 or at a cost of $0.59 per wet ton ($0.65/metric ton). This cost will be absorbed by the Army Corps of Engineers. Some assurance that these costs will be well spent may result from close coordination of CROG with a Corps representative recently appointed to CAC's conservation sub-committee (See Legal/Institutional in Section 6.6). In addition these costs will insure reduced levels of turbidity in river water which was often recorded during and after period of precipitation.

6.6.10 Overview of BMP's In CROG

Planners in the CROG area have developed a comprehensive scheme for management of residual wastes. Addressing all of the major waste categories, they have initiated both preventive and ameliorative practices, including land spreading, landfilling, pond disposal, lagooning, land reclamation, chemical treatment, shredding and separation, recycling/ recovery, centralization of treatment facilities, and relocation of facilities within a feasible legal and institutional framework. These practices are used in conjunction with secondary supporting techniques, such as grading, lining, diking, trenching, and other structural methods by which further degradation of water quality can be prevented.

Not all of these practices could be undertaken simultaneously; delays resulted from both technical and institutional barriers to effective action. Eliciting cooperation and maintaining the momentum toward improvement has been a major aspect of the total planning effort.

Further, the CROG planners are aware that these Best Management Practices are not static, but must undergo continual assessment as new problems arise and new technologies appear.

Planners must recognize that an agency, such as CROG cannot presently implement its plans directly. As was described earlier in the Handbook, planning agencies are dependent upon other legally-empowered agencies and traditional organizations for plan implementation (See Sections 5.1.3 and 5.2.5.8). Planning agencies similar to CROG can organize and analyze data on an areawide or State basis transcending traditional jurisdictional interests and boundaries. Planning agencies can evaluate broad concerns, such as a variety of residual waste categories and problems, land use, transportation, finance, legal questions, and potential institutional arrangements and their interrelationships. This broad view allows planning agencies to arrive at plans that incorporate provisions for implementation by others, such as describing the appropriate form of intergovernmental mechanisms. Planning agencies can also help coordinate these implementation efforts and serve as an arbitrator in implementation. Agencies like CROG can provide the medium for citizen participation and a forum for the public's preferences. These are functions that are beyond the realm of any single implementing organization, such as a sewer district.

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APPENDIX A. FIELD MONITORING AND SAMPLING

INTRODUCTION

Before developing a monitoring system, the planner must determine exactly what is expected of it. Is it merely to track the progress of expected ground water contamination? Is it to serve as a warning that a containment method has failed? An effective monitoring system for waste disposal lands should provide adequate data to permit an accurate evaluation of immediate and potential long-term contamination effects. In practice, however, most monitoring facilities are designed to detect only surface-water and ground water pollution, with little if any attention given to possible short-term or long-term effects of background pollutants that reenter the environment from soil or plant storage areas.

In design of the monitoring system. The planner should evaluate his need for other than routine information, which will affect the kinds of measurements taken as well as their frequency. If data are needed on surface runoff, for example, the system should provide not only for periodic water sampling and analysis but for concurrent volume-of-flow measurements and perhaps for nonscheduled sampling immediately after major precipitation periods.

The planner should consider the relative merits of the available monitoring techniques for application to his project. Recent studies, for example, suggest that monitoring systems based on observation wells may not be the most effective means of tracing contaminant flow or of determining concentrations of chemicals in ground waters. Chemical analyses of soil core samples are sometimes more effective in yielding good data and usually provide a faster, easier, and less expensive monitoring method (Ref. A-1, 2).

As a base for the following discussion of disposal site monitoring, Figure A-1 depicts the possible avenues by which contaminants from the site can enter the environment. All of these avenues must be effectively monitored to provide optimum detection results.

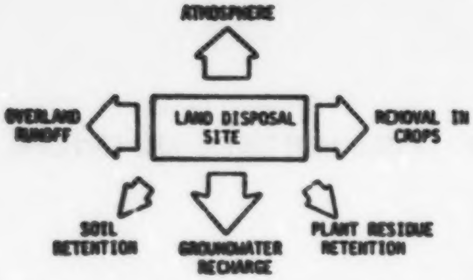

Figure A-1. Paths of contaminants from disposal site to the environment.

SAMPLING POINT DISTRIBUTION

Distribution and number of sampling points usually are dictated by geologic, hydrologic, and chemical complexities. Under ideal conditions, where the underlying earth materials are fairly homogeneous, impermeable, and uniformly sloping in one direction, only three sampling points should be required. For optimum results, these three points are equally spaced on a line through the center of the disposal area, extending from the area of highest water table and earth material base elevation directly downslope to the area of lowest elevations on the property. Theoretically, under such an arrangement, the direction of ground water flow and the changes in chemical concentration with distance of travel should be readily discernible providing ground water flow is uniform. In nature, however the earth materials are not homogeneous, and the flow paths of ground water through any given profile may be extremely variable and complex. In addition, more than one aquifer may be present, and if so, each of these may have to be monitored by use of a number of three-station lines. In complex systems such as these, the preferable pattern of sampling stations is a square-grid network uniformly distributed throughout the entire disposal area and the contiguous downgradient lands likely to be adversely affected.

RECOMMENDED MONITORING PROCEDURES

Background data on all potential contamination-dissipation regimes should be obtained at all sampling stations just prior to the first application of waste material on the disposal land. At least one sampling station should be positioned far enough upslope from the disposal lands to ensure that its data always will be representative of natural-state conditions in the area. Also, before disposal begins, collection and evaluation of all available topographic, soil, vegetation, fauna, geologic and hydrologic maps, and other published information of this type is recommended. These data and a detailed inventory of all surface-water bodies and wells in the immediate vicinity (including complete chemical analyses of water samples from each of these) may prove to be invaluable later on if definition of environmental degradation from the waste disposal site ever is required.

After the site has been placed in service, sampling from all designated sampling stations should be on a frequency that ensures accurate meaningful data. Depending upon the facility to be investigated, some of the six primary dissipation avenues shown in Figure A-1 may not have to be continuously monitored after operations begin. For example, solid waste landfills that are properly installed and efficiently operated should not cause significant degradation of air, surface water, soil, or vegetational quality. On the other hand, monitoring instrumentation for all six of the major dissipation regimes might have to be installed at a land spreading or irrigation disposal site.

VEGETATION

Plant uptake of toxicants can be effectively evaluated by chemical analysis of composite vegetational samples collected periodically from each of the regular sampling stations (Ref. C-1). The primary reason for this sampling is to ascertain the quantity of pollutants leaving the field in harvested portions of crops, or being returned to the field for possible later recycling in unharvested plant residue. Plant samples should be collected just at harvest time, or if the entire plant is left in the field, after the plant becomes dormant in the late fall. At such times, maximum toxicant accumulations should be present.

SURFACE WATER

Overland runoff from the disposal area may never occur. If it does happen frequently and in appreciable amounts, monitoring facilities must be provided to obtain representative water samples and corresponding volume-of-flow measurements. Sampling should be done throughout the entire period when overland runoff is occurring to provide data required for plotting of meaningful concentration and volume-of-flow graphs. A comparable procedure also must be followed to monitor any drainage-title discharge that might be associated with a land-disposal project.

SOILS

Soil retention and possible later release of stored toxicants should be monitoried periodically by chemical analyses of soil core samples obtained from the entire vertical column of earth material likely to be adversely affected. A minimum of three and no more than nine core test stations are required on each parcel of land receiving waste material.

In arid regions, if waste liquid application rates always are maintained below evaportranspiration losses, soil monitoring probably would not be required except possibly to define the potential for long-term plant toxicity buildup (Ref. C-1). In humid regions, frequent soil sampling may have to be considered as an essential part of all monitoring programs. In these regions normal precipitation exceeds evapotranspiration rates at least part of most years so that periodic ground water recharge and surface-water runoff inevitably occur. Thus, the potential is great for soil- or plant-retained contaminants to migrate from the site. For this reason, soil samples may have to be collected in humid regions as often as twice yearly at each sampling stations. The samples should be from depth intervals no greater than 5 feet apart and at every lithologic change. Each test hold should extend into the uppermost dense, impermeable formation that everywhere in the area lies below the lowest water-table elevation that is likely to ever occur.

Initial soil-core test probes made to obtain background data should be placed at the center of each designated sampling station. Subsequent cores may be taken at appropriately divided grid intersection points within the allotted area of the station. If possible, each core hole should be kept open for approximately 24 hours so that a meaningful water-level reading can be obtained for use in defining the water-table gradient. Then the hole should be refilled to the surface with compacted clay or dry bentonite to prevent possible later entry of contamination from the surface to underlying deposits via this excavation.

Several methods of soil sample collection are acceptable. For unconsolidated formations, dry-sampling techniques such as coring with Shelby-tube or split-spoon samples, drilling with air rotary equipment, or augering with either hollow stem or solid flight augers are normally recommended, usually in this listed order of preference. The wet-sampling technique most commonly used in unconsolidated materials and in most consolidated rock formations is cable tool or direct-circulation mud rotary drilling. The wet-sampling technique normally is not as preferable because the drilling liquids used during excavation may infiltrate the formations being sampled.

As soon as possible after soil samples have been collected, they should be sealed in appropriate airtight containers to prevent loss of moisture content and to minimize atmospheric effects. The more complex contaminant constituents may require use of special preservation additives and temperature-control measures. Glass containers with alluminum- or teflon-lined caps usually must be employed for storing and transporting soil samples containing hydrocarbon contaminats.

GROUND WATER

Ground water contamination from land disposal sites should be minimal if the site and contiguous lands are underlain by only dense, impermeable clay or shale formations. In such earth materials, the rate of ground water movement may be less than 10 feet per year; thus, toxic chemical buildup and the movement of toxicants beneath such affected lands usually can be effectively monitored by chemical analyses of earth samples from only a few strategically placed core holes. If, however, the unconsolidated earth material above impermeable bedrock contains several extensive water-bearing stringers or beds of silt, sand, or gravel, core-test monitoring may not be applicable or may have to be supplemented by chemical analyses of ground water samples. These are obtained from properly positioned observation wells in each water-bearing unit.

A dry method of drilling (hollow stem auger or air rotary) is preferred for installation of observation wells to ensure minimal adulteration of screened portions with liquids from external sources. In very permeable aquifers however, a mud rotary type of excavation may have to be used to prevent caving before the required casing, screen, and sealant materials are installed.

Monitor-well casing and screen must be of a material not readily affected by contaminants in the waters sampled. The inside diameter of the casing should be large enough to permit ready collection of periodic water samples with a pump, bailer, or some other water-extraction device. A 2- to 4-inch diameter well usually is adequate, although diameters as small as 1 inch have been successfully employed. Large diameters wells generally are undesirable because they are difficult to flush prior to sampling.

Most monitor wells now in service are samples with a bailer-type device that is repeatedly lowered and removed from the well until all water stored in the casing has been removed and the hole contains only fresh water from the aquifer. When several feet of stored water must be removed, considerable time and effort are required to obtain a sample by the bailer method. Another disadvantage is that with repeated use (often without proper cleaning) a dirty bailer may introduce contaminants from one installation into another.

For these reasons, permanently installed pumping equipment is desirable for monitor wells that require frequent sampling. Pumps suitable for this use may be prohibitive in cost, however, particularly if a considerable number of wells must be pumped. In such cases an air-lift pumping device may be appropriate.

After a monitoring well is installed, considerable well development work may be required. Of primary concern is the removal of any surface-derived contamination inadvertently introduced during construction. Well development usually consists of frequent surging and flushing until the installation produces relatively clear and chemically stable water. This may be accomplished in only a few hours if the well is screened in sand or gravel, but may require a month or more if the well is finished in predominantly silt or clayey water-bearing units. Routine monitoring of an observation well should begin only after full development.

Every monitoring well should be flushed of its stored water immediately prior to each sampling. When the well cannot be pumped dry, flushing equivalent to about 5 well-casing volumes is usually considered adequate. As with soil samples, the collected water samples should be preserved in a state as natural as possible until laboratory analysis can be completed. Preservation may require special chemical additives, storage containers that are nonreactive, and temperature control measures.

Some parameters, such as pH, temperature, and alkalinity should be determined from a sample in the field. Further analysis of most of the chemical constituents is usually done in a laboratory (See Appendix B).

PIEZOMETERS

Although the terms piezometer and observation well are commonly used interchangeably, there is a significant difference between them. As implied by its name, a piezometer is a pressure measuring device, frequently used for monitoring: 1) water pressure in earthen dams or under foundations, and 2) artesian pressure in confined aquifers. The piezometer, a porous tube or plate in the former and a screened well or open hole in the latter, is isolated from other pressure environments by an impermeable seal of either clay or cement. Water samples representative of a specific horizon can be obtained from well-type piezometers, a highly desirable factor in designing a monitoring program. Piezometers can also be used to measure vertical head differences under unconfined conditions if the well screen is properly isolated by an impermeable seal immediately above the screen. Any well constructed without this seal cannot be considered a piezometer. However, there is a significant difference in application to landfill leachate monitoring between a piezometer and a well screened over a single vertical interval. The relatively impermeable annular seal will prevent downward movement of leachate into contaminated zones of the aquifer.

TRENCH LYSIMETERS

Several investigators have used trench lysimeters to sample gravity water from irrigation or rainfall in the near-surface zone of aeration. In normal practice, a wood-reinforced trench or concrete-ring caission is installed to a depth of 10 to 30 feet below land surface. Pans or open end pipes are forced out of the trench or caission, through access ports into the subsoil. These collecting devices intercept percolating water and conduct it to sample bottles inside the trench. Only after irrigation or precipitation is there enough water infiltrating the subsoil to collect a sample (Ref. A-3, 4, 5).

Due to the potential accumulation of hazardous gases generated by decomposition of landfill material, the use of an open trench or caisson to sample leachate in or under a landfill can be risky. Artificial ventilation and gas monitoring devices are required to prevent injury to personnel collecting samples inside the trench. All in all, the method has little to recommend it.

PRESSURE VACUUM LYSIMETERS

Suction lysimeters have been used by a variety of investigators, including engineers, soil scientists, and hydrogeologists, to obtain samples of in-situ soil moisture. They are predominantly in the zone of aeration, but can easily be used to sample ground water. This device, in its most improved form, consists of a porous ceramic cup capable of holding a vacuum, a small-diameter, sample accumulation chamber of PVC pipe, and two sampling tubes leading to the surface. Once the lysimeter is emplaced, a vacuum is applied to the cup. Soil moisture moves into the sampler under this gradient, and a water sample gradually accumulates. The vacuum is then released and pressure is applied, forcing the accumulated water to the surface through the sampling tube.

The technology of lysimeter utilization is well established. Lysimeters have been used to trace: pollution from septic tanks, synthetic detergents, and colliery spoil heaps (Ref. A-5, 6, 7, 8).

SURFACE WATER

Streams which are ground water discharge areas for disposal sites can often be used to advantage in a monitoring program. Any deterioration in quality between a point just upstream of the site to a point just downstream would be a direct indication of contamination. Prior to the adoption of stream monitoring, however, it is essential to determine that the residual site is the only potential source of contaminants in the reach under consideration - a sewer outfall on the opposite bank, for example, would probably make this approach infeasible. Sampling points, methods, and frequency must be determined on the basis of the characteristics of the stream involved. They are highly site specific. Stream monitoring may also be used to determine the effects of deliberate or accidental surface runoff.

Existing springs in the vicinity of the site are obvious candidates for monitoring, as are seeps which may develop after the site becomes operational.

ELECTRIC RESISTIVITY

The use of the electrical resistivity method to detect and delineate ground water contamination is described in Section 4.4.5.1. Because of the expense involved, it is not suitable as a routine monitoring method, but in some cases it can be valuable in long-term studies.

REFERENCES

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A-2 Walker, William H., and J.P. Gibb., Field Verification of Industrial Hazardous Material Migration from Land Disposal Sites in Humid Regions. First Annual Progress Report for Grant R803216, EPA, Cincinnati, Ohio (Unpublished Report).

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A-6 Manbeck, D.M. Presence of Nitrates Around Home Disposal Waste Sites. 1975 Annual Meeting Preprint, Paper No. 75-2066. American Society Agricultural Engineers. 1975.

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A-8 James, T.E. Colliery Spoil Heaps in J.A. Cole, Ed. Ground Water Pollution in Europe. Water Information Center, Port Washington, New York. 1974.

APPENDIX B - LABORATORY PROCEDURES FOR RESIDUAL WASTES

The purpose of this section is to acquaint the planner with the procedures, methods of collection and preservation of residual waste related samples, and the basic analyses performed for determining residual waste deposition effects upon water quality. It is assumed that qualified laboratory personnel would actually collect the samples and analyze them either in a field or permanent laboratory (Ref. B-1).

PRESERVATION

Preservation of samples is difficult because most all preservatives interfere with some of the tests. Immediate analysis is ideal; however, since this is usually impossible for most tests, storage at a low temperature (4C) is perhaps the best way to preserve most samples until the next day. No single method of preservation is entirely satisfactory, and the preservative should be chosen with due regard to the determinations that are to be made. Table B-1 is a list of suggested preservation methods for various parameters plus the length of time they can be held prior to analysis. A general preservative for sludge and sediment samples is to add 5 grams of sodium benzoate or 1 milliliter of sulfuric acid for each 80 grams of sample, provided that these preservatives do not interfere with the tests to be made.

CHAIN OF CUSTODY

It is possible that analytical results could be used as evidence in legal proceedings For this reason it is important that the presence of the sample be accounted for from the time of collection until the sample is analyzed.

This accounting is generally referred to as "chain of custody" (Ref. B-2). Since most samples must be transported back to the laboratory for analysis, it is good practice to treat each sample as though the results will be used in legal proceedings.

The field notebook is an excellent and acceptable means of assistance in the recall of facts and circumstances in the event of adjudication. Examples of information to be recorded should include the following.

Table B-1. METHODS OF PRESERVATION

Parameter	Preservation	Max. time[a]
pH	Cool @ 4°C	4 hrs.
Conductivity	Cool @ 4°C	24 hrs.
Residue	Cool @ 4°C	7 days
COD	H_2SO_4 <2pH	7 days
TOC	Cool @ 4°C H_2SO_4 <2pH	24 hrs.
Kjeldahl nitrogen	Cool @ 4°C H_2SO_4 <2pH	7 days
Chloride	None required	
Sulfate	Cool @ 4°C	7 days
Phosphate	Cool @ 4°C	7 days
Alkalinity	Cool @ 4°C	24 hrs.
Acidity	Cool @ 4°C	24 hrs.
Nitrate	Cool @ 4°C H_2SO_4 <2pH	24 hrs.
Nitrite	Cool @ 4°C	24 hrs.
Ammonia	Cool @ 4°C H_2SO_4 <2pH	24 hrs.
Metals	HNO_3 <2pH	6 mos.
Hardness	HNO_3 <2pH	7 days
BOD	Cool @ 4°C	24 hrs.

[a] While maximum times have been listed, samples should be analyzed as soon as possible.

Source: Ref. B-1.

Sampling location

Time and date

Weather conditions

Sampling method - grab sample, automatic composites, etc.

Method of preservation

Disposition of sample - transferred to John Smith for transport to lab, mailed to lab, stored prior to transporting to lab, etc.

The sampler should sign each page of his field notebook in order to strengthen the case for its authenticity. If the sampler transfers the samples to someone else, the person receiving the samples should indicate so and sign the field notebook. If samples are sent through the mail, they should be sent by registered mail. Another good practice when shipping samples through the mail is to place a seal across the access point to the container. This seal is signed and dated by the person sending the samples and also by the person receiving the samples prior to breaking the seal. This method is used by some agencies within the U.S. Environmental Protection Agency. Also, although not always practiced, one of the people associated with the laboratory should be designated to safeguard the sample in the laboratory. The sample custodian should maintain a permanent record containing information such as

Type of sample
Sampling location
Date sampled
Date received
Sample number (assign one if necessary)
Sample assigned to whom
Date assigned

Unused portions of the sample should be stored for a specified time period until results have been verified.

QUALITY CONTROL

A good quality control program in the laboratory has two primary functions. First, the program should monitor the reliability (truth) of the results reported. The second function is the control of quality in order to meet the program requirements for reliability. Regardless of the analytical method used in the laboratory, the specific methodology should be carefully documented.

TYPICAL TESTS

Some typical tests to indicate water quality may include the following.

pH - The logarithm of the reciprocal of the hydrogen activity in moles per liter. The pH range is 0-14 with 0 being extremely acidic and 14 being extremely basic.

Conductivity - A measure of the capacity of the sample to convey an electric current. This is proportional to the total concentration of ionic solute.

Residue - The material left after evaporating or filtering the sample. Determinations may include total residue, volatile residue, filterable and non-filterable residue and settleable residue.

Chemical Oxygen Demand (COD) - A measure of the organic matter that is susceptible to oxidation by a strong chemical oxidant, expressed as the oxygen equivalent.

Total Organic Carbon (TOC) - A measure of the amount of organic carbon present in the sample.

Total Kjeldahl Nitrogen - The sum of free-ammonia and organic nitrogen compounds which are converted to ammonia sulfate under the prescribed digestion conditions.

Chloride - A measure of the concentration of soluble chloride ion.

Sulfate - A measure of the concentration of sulfate ion ($SO_4^=$) in mg/l.

Phosphate

Total - A measure of all forms of phosphate converted by digestion to the soluble orthophosphate.

Ortho - A measure of those phosphates that respond to the colorimetric test without preliminary hydrolysis or oxidation digestion.

Alkalinity - A measure of the capacity of the sample to accept protons. (Its ability to neutralize strong acids.)

Acidity - A measure of the capacity of the sample to donate protons. (Its ability to neutralize strong bases.)

Nitrate - A measure of the concentration of nitrogen as the nitrate ion (NO_3^-).

Nitrite - A measure of the concentration of nitrogen as the nitrite ion (NO_2^-).

Ammonia - A measure of the concentration of nitrogen as ammonia (NH_3).

Metals - A measure of the concentration of the specific metal. Analysis may be for total, dissolved, etc.

Hardness - A measure of the concentration of polyvalent metals, mainly calcium and magnesium, but will also include iron, zinc and copper when present in significant amounts. Results are expressed as calcium carbonate equivalents.

Biochemical Oxygen Demand (BOD) - A measure of the oxygen demand exerted by microorganisms during uptake of degradable substrates and by chemical oxidation reactions.

REFERENCES

B-1. Manual of Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, National Environmental Research Center. Cincinnati, Ohio, 1974. 298 p.

B-2. Norman, Jeffrey. Chain of Custody and Holding of Samples - Legal Considerations. U.S. Environmental Protection Agency, Office of Air Programs, Program Guidelines and Information Branch. Research Triangle Park, North Carolina. November, 1972.

APPENDIX C

SITE EVALUATION CHECKLIST FOR LAND DISPOSAL OF RESIDUALS

(Adapted form "Evaluation of Land Application Systems"
EPA-430/9-75-001)

All potential sites should be considered on the basis of the criteria listed in this section, and should be reevaluated in the light of design considerations and environmental assessment.

1. General description
   - a. Location
     - (1) Distance from collection area or treatment plant
     - (2) Elevation relative to collection area
   - b. Compatibility with overall land use plan
     - (1) Current use
     - (2) Proposed future use
     - (3) Zoning and adjacent land use
     - (4) Proximity to current and planned developed areas
     - (5) Is there room for future expansion?
   - c. Proximity to surface water
   - d. Number and size of available land parcels
2. Description of environmental characteristics
   - a. Climate
     - (1) Precipitation analysis and seasonal distribution
     - (2) Storm intensities
     - (3) Temperature, with seasonal variations

- (4) Evapotranspiration
- (5) Wind velocities and direction

b. Topography

- (1) Ground slope
- (2) Description of adjacent land
- (3) Erosion potential
- (4) Flood potential
- (5) Extent of clearing and field preparation necessary

c. Soil characteristics

- (1) Evaluation by soil specialists
- (2) Type and description
- (3) Infiltration and percolation potential
- (4) Cation exchange capacity (CEC)(see note C-1)

d. Hydrogeology

- (1) Evaluation by hydrogeologist
- (2) Description of geologic setting
- (3) Depth to groundwater, and fluctuations
- (4) Description of aquifer systems
- (5) Background quality of groundwater
- (6) Current and planned use
- (7) Location and pumpage of existing wells
  - (a) On site
  - (b) Adjacent to site

(8) Natural discharge areas for water-table aquifer

e. Receiving water (other than ground water)

(1) Type of body

(2) Current use

(3) Existing quality

(4) Is it water-quality limited?

(5) Is it effluent limited?

(6) Water rights

Note C-1: The CEC equation, developed by the U.S. Department of Agriculture, may serve as an approximate indicator of plant uptake of heavy metals in soils that can be adjusted and held at a pH of 6.5 or greater. As the equation may not yield precise indication of plant uptake it should be used with caution.

Total residual (dry wt tons/acre) =

$$\frac{36{,}000 \times \text{CEC}}{\text{ppm Zn} + 2\,(\text{ppm Cu}) + 4\,(\text{ppm Ni}) - 300}$$

where:

CEC = cation exchange capacity of the soil prior to deposition of residual meq/100 g.

ppm = mg/kg dry wt of sludge.

This equation limits the heavy metal additions calculated as zinc equivalent to 10 percent of the CEC. The zinc equivalent takes into account the greater plant toxicities of copper and nickel.

Residuals having a cadmium content greater than one percent of its zinc content should not be applied to cropland except under controlled conditions.

Source: Ref. C-1.

REFERENCES

C-1 Wyatt, J.M., and P.E. White, Jr. Sludge Processing, Transportation, and Disposal/Resource Recovery: A Planning Perspective. Engineering Science, Inc. EPA Contract No. 68-01-3104. April 1975.

APPENDIX D

GLOSSARY

Activated Sludge - Sludge floc produced in raw or settled wastewater by the growth of zoological bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

Aeration - (1) The bringing about of more intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, or (c) agitating the liquid to promote surface absorption of air. (2) The supplying of air to confined spaces under nappes, downstream from gates in conduits, etc., to relieve low pressures and to replenish air entrained and removed from such confined spaces by flowing water. (3) The relieving of the effects of cavitation by admitting air to the section affected.

Aerobic Digestion - Digestion of organic matter by means of aeration.

Alum - A common name, in the water and wastewater treatment field, for commercial-grade aluminum sulfate ($Al_2 (SO_4)_3 \cdot 14H_2O$) used for coagulation.

Amortization - The act or process of retiring a debt, usually with equal payments at regular intervals over a specific period of time.

Anaerobic Digestion - The metabolism of organic matter brought about through the action of certain microorganisms in the absence of elemental oxygen.

Annelids - Comprises the segmented worms. Includes the familiar earthworms and leechs as well as a number of freshwater and marine species.

Aquifer - A stratum or formation of permeable material that will yield ground water in useful quantities.

Aquifer, artesian - An aquifer in which ground water is confined under pressure greater than atmospheric. Also known as a confined aquifer.

Aquifer, water-table - An aquifer in which the water is unconfined, with the water table defining the upper surface of the zone of saturation. Also known as an unconfined aquifer.

Backwashing - The operation of cleaning a filter by reversing the flow of liquid through it and washing out matter previously captured in it. Filters would include true filters such as sand and diatomaceous-earth types but not other treatment units such as trickling filters.

Basin - (1) A natural or artifically created space or structure, surface or underground, which has a shape and character of confining material that enable it to hold water. The term is sometimes used for a receptacle midway in size between a reservoir and a tank. (2) The surface area within a given drainage system. (3) A shallow tank or depression through which liquids may be passed or in which they are detained for treatment or storage.

Benthic Organisms - The aggregate of organisms living on or at the bottom of a body of water.

Biodegradation (biodegradability) - The metabolic destruction or of natural or synthetic organic materials by the microorganisms populating soils, natural bodies of water, or wastewater treatment systems.

Biological Oxidation - The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable (less putrifiable) matter.

Biological Stabilization - Reduction in the net energy level, and the tendency to purify, or organic matter as a result of the metabolic activity or organisms.

Biological Treatment - Organic waste treatment in which bacteria and/or biochemical action is intensified under controlled conditions.

BOD (Biochemical Oxygen Demand) - An indirect measure of the concentration of biologically degradable material present in organic wastes. It is the amount of free oxygen utilized by aerobic organisms when allowed to attack the organic matter in an aerobically maintained environment at a specified temperature (20°C) for a specific time period (5 days). It is expressed in milligrams of oxygen per kilogram of solids present (mg/kg = ppm = parts per millions).

Cation exchange capacity (CEC) - The capacity of a soil for replacing adsorbed cations by cations in solution. Expressed in millequivalents per 100 grams.

Cellulose - Plant cell walls that are formed by the combination of many molecules of glucose.

Centrifugal dewatering of sludge - The partial removal of water from wastewater sludge by centrifugal action.

Chemical Fixative - A chemical material capable of locking-in and solidifying waste residuals into a nonleachable state. These materials are sometimes referred to as encapsulating materials.

Chemical Oxidation - Oxidation of organic substances without benefit of living organisms. Examples are by thermal combustion or by oxidizing agents such as chlorine.

Chlorine - An element ordinarily existing as a greenish-yellow gas about 2.5 times as heavy as air. At atmospheric pressure and a temperature of -30.1°F, the gas becomes an amber liquid about 1.5 times as heavy as water. The chemical symbol of chlorine is Cl, its atomic weight is 35.457, and its molecular weight is 70.914. Typically used for disinfection.

Clarification - Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

Coagulant - A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that absorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric sulfate and alum.

COD (Chemical Oxygen Demand) - An indirect measure of the biochemical load exerted on the oxygen assets of a body of water when organic wastes are introduced into the water. It is determined by the amount of potassium dichromate consumed in a boiling mixture of chromic and sulfuric acids. The amount of oxidizable organic matter is proportional to the potassium dicromate consumed. Where the wastes contain only readily available organic microbial food and no toxic matter, the COD values can be correlated with BOD values obtained from the same wastes.

Coliform Bacteria - A group of bacteria predominantly inhabiting the intestine of man or other mammals.

Colloids - (1) Finely divided solids which will not settle but may be removed by coagulation of biochemical action or membrane filtration; they are intermediate between true solutions and suspensions.

Confined aquifer - See Aquifer, artesian.

Dewater - (1) To extract a portion of the water present in a sludge or slurry. (2) To drain or remove free water from an enclosure.

Diatomaceous-Earth Filter - A filter used in water treatment, in which a built-up layer of diatomaceous earth serves as the filtering medium.

Dissolved Oxygen - The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation. Abbreviated DO.

Dissolved Solids - Theoretically, the anhydrous residues of the dissolved constituents in water. Actually, the term is defined by the method used in determination. In water and wastewater treatment the Standard Methods tests are used.

Drawdown - The lowering of ground water levels in and around a well caused by pumping the well.

Effluent - (1) A liquid which flows out of a containing space. (2) Wastewater or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, industrial treatment plant, or part thereof.

Enterococci - A group of cocci having its normal habitat in the intestines of man or other animals.

Equipotential line - A line connecting all points of equal elevation of the water table or potentiometric surface. A ground water contour.

Eutrophication - The natural process of the maturing (aging) of a lake; the process of enrichment with nutrients, especially nitrogen and phosphorus, leading to increased production of organic matter.

Evapotranspiration - The transfer of water to the atmosphere by the combined processes of evaporation and transpiration (g.v.).

Filtration - The process of passing a liquid through a porous medium for the removal of suspended or colloidal material contained in the influent liquid by a physical straining action. The trickling filter process used in waste water treatment is a method of contacting dissolved and colloidal organic matter with biologically active aerobic slime growths, and is not a true filtration process.

Fixed Solids - The residue remaining after ignition of suspended or dissolved solids according to standard methods.

Flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means.

Fugitive Dust - Pollutant emissions which are not confined in process streams. Major sources are: unpaved roads and airstrips; agricultural tilling; land development; residential, industrial, highway, and commercial construction; quarrying, mining, and tailings; aggregate storage sites; and cattle feedlots.

Groundwater - Subsurface water in the zone of saturation.

Hardness - A characteristic of water, imparted by salts of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides and nitrates, that cause curdling of soap and increased consumption of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminum, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate.

Heavy Metals - Metals that can be precipitated by hydrogen sulfide in acid solution, some of which include lead, zinc, cadmium, mercury, arsenic, and copper.

Hydraulic Gradient - The difference in elevation of the water table or potentiometric surface over a unit horizontal distance along a flow line.

Infiltration - Strictly defined, the movement of water through the soil surface into the soil. As used herein, it includes percolation, the movement of water through the soil and subsoil into the ground water body.

Leachate - Water that has percolated through solid waste, from which it has removed soluble components plus insoluble or poorly-soluble material in fine suspension.

Leaching - The removal of soluble constituents (dissolved solids) from soil, rock, or sludge deposits by percolating water. Also the disposal of liquid through porous strata.

Liquid Manure - A suspension of livestock manure in water, in which the concentration of manure solids is low enough so the flow characteristics of the mixture are more like those of Newtonian fluids than plastic fluids.

Nonpoint Sources - For the purposes of this task they will be defined as those infiltration, implace pollutants, and diffuse runoff sources, induced by man's activities, which are directly or indirectly related to meteorological events and result in the alteration of the chemical, physical, biological and radiological integrity of water.

Nutrient - As used herein, any element essential to plant growth, such as nitrogen or phosphorus.

Pathogenic Bacteria - Bacteria which may cause disease in the host organisms by their parasitic growth.

Percolation - See Infiltration.

Permeability - In a qualitative sense, the relative ease with which a formation will transmit water. Quantitatively, the volume of water transmitted per unit time across a unit area, under a unit hydraulic gradient (Coefficient of permeability).

Plume - The path taken by the continuous discharges from a source of contamination.

Polychaetes - Class of common marine worms.

Polyelectrolyte - (ORG CHEM) - A natural or synthetic electrolyte with high molecular weight, such as proteins, polysaccharides, and alkyl addition products of polyvinyl pyridine; can be a weak or strong electrolyte; when dissociated in solution, it does not give uniform distribution of positive and negative ions (the ions of one charge are bound to the polymer chain while the ions of the other sign diffuse through the solution).

Porosity - The percentage of voids in a volume of rock.

Primary Treatment - The first major (and sometimes only) treatment of waste and wastewater, usually sedimentation. Involves the removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter.

Protozoa - Any of a number of one-celled animals, usually microscopic, belonging to the lowest division of the animal kingdom.

Pyrite - A hard, brittle, brass-yellow mineral with metallic luster. Composition is iron disulfide which is the key to its importance in combination with oxygen to create acid-mine drainage.

Raw Sludge - That which is settled out in the primary settling tanks. Typical solids content ranges from 2 to 7%.

Raw Wastewater - Wastewater before it receives any treatment.

Raw Water - (1) Untreated water; usually water entering the first treatment unit of a water treatment plant. (2) Water used as a source of water supply taken from a natural or impounded body of water, such as a stream, lake, pond, or underground aquifer.

Recharge - The addition of water to the ground water system by natural or artificial processes. That portion of precipitation that enters the ground water body.

Redox Potential (Eh) - Represents the relative intensity of oxidizing or reducing conditions in solutions. Also known as oxidation-reduction potential, or simply oxidation potential. It is defined by the Nenust equation.

Runoff - Direct or overland runoff is that portion of rainfall which is not absorbed by soil, evaporated, or transpired by plants, but finds its way into streams as surface flow. That portion which is absorbed by soil and later discharged to surface streams is ground water runoff.

Secondary Sludge - That which settles out in the secondary settling tanks. Solids content range from 1 to 5%.

Secondary Treatment - The treatment of waste and wastewater by biological methods after primary treatment by sedimentation.

Sedimentation - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling.

Settleable Solids - (1) That matter in wastewater which will not stay in suspension during a preselected settling period.

Sludge Cake - The sludge that has been dewatered by a treatment process, the moisture depending on type of sludge and manner of treatment.

Soft Water - Water having a low concentration of calcium and magnesium ions. According to U.S. Geological Survey criteria, soft water is water having a hardness of 60 mg/l or less.

Specific Capacity - The yield of a well per unit drawdown, usually expressed as gallons per minute per foot. For any given well it is not a constant, but decreases with increasing yield.

Transmissivity - The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. The coefficient of permeability multiplied by the thickness of the aquifer. Called transmissibility in older literature.

Transpiration - The process through which water is returned to the atmosphere through the tissues of living plants.

Trickling Filter - Filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slate or other porous media, over which wastewater is distributed or applied in drops, film, or spray from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the wastewater.

Tubifex - An aquatic worm (oligochaete) which lives in stagnant mud and lake and stream sediments.

Turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

Unconfined Aquifer - See Aquifer, water table.

Volatile Solids - That portion of the total or suspended solids residue which is driven off as volatile (combustible) gases at a specified temperature and time (usually at 600°C for at least one hour).

Water Quality - The chemical, physical, and biological characteristics of water with respect to its suitability for a particular purpose. The same water may be of good quality for one purpose or use, and bad for another, depending on its characteristics and the requirements for the particular use.

Water table - The surface in an unconfined ground water body at which the pressure is atmospheric. It defines the top of the zone of saturation.

Wet Scrubber - A countercurrent absorption tower using alkaline additives to maintain SO_2 and/or particulate absorption from the combustion gas stream.

Zone of saturation - The zone in which interconnected interstices are saturated with water under pressure equal to or greater than atmospheric.

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